NPS-09-99-013

Naval Postgraduate School
Monterey, California 93943-5138

SUMMARY
OF
RESEARCH
1998

Department of Operations Research

Richard Rosenthal
Chair

Gerald Brown
Associate Chair for Research

Prepared for: Naval Postgraduate School
Monterey, CA 93943-5000

DTIC QUALITY INSPECTED 2

19991227 044

NAVAL POSTGRADUATE SCHOOL
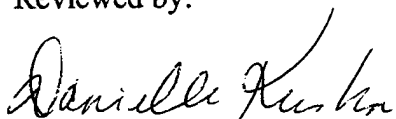Monterey, California

Rear Admiral R.C. Chaplain, USN
Superintendent

R. Elster
Provost

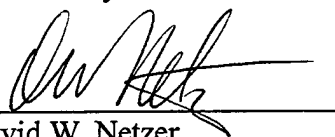This report was prepared for the Naval Postgraduate School, Monterey, CA.

Reproduction of all or part of this report is authorized.

Reviewed by:

Danielle A. Kuska
Director, Research Administration

Released by:

David W. Netzer
Associate Provost and Dean of Research

REPORT DOCUMENTATION PAGE	Form approved OMB No 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE August 1999	3. REPORT TYPE AND DATES COVERED Summary Report, 1 January 1998 - 31 December 1998

4. TITLE AND SUBTITLE
Summary of Research 1998, Department of Operations Research

5. FUNDING

6. AUTHOR(S)

Faculty of the Department of Operations Research, Naval Postgraduate School

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Naval Postgraduate School
Monterey, CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

NPS-09-99-013

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Naval Postgraduate School
Monterey, CA 93943-5000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

The views expressed in this report are those of the authors and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

A

13. ABSTRACT (Maximum 200 words.)

This report contains summaries of research projects in the Department of Operations Research. A list of recent publications is also included which consists of conference presentations and publications, books, contributions to books, published journal papers, technical reports, and thesis abstracts.

14. SUBJECT TERMS

15. NUMBER OF PAGES
98

16. PRICE CODE

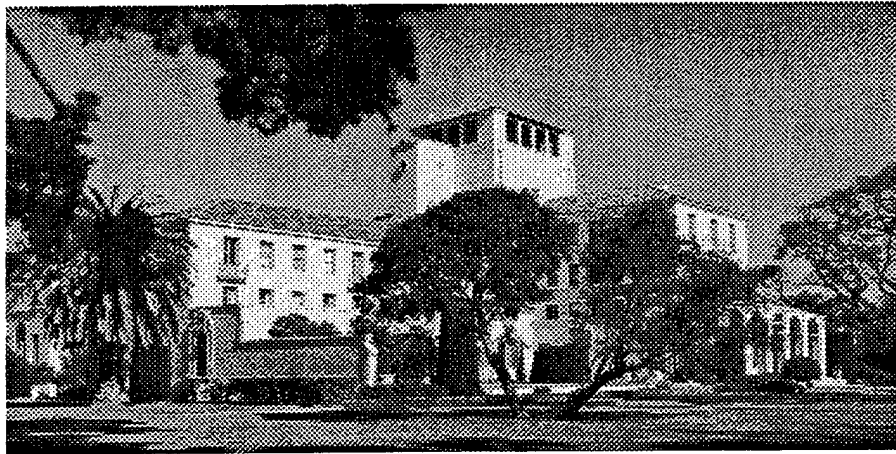| 17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT

DEPARTMENT OF OPERATIONS RESEARCH

Richard Rosenthal
Chair

THE NAVAL POSTGRADUATE SCHOOL MISSION

The mission of the Naval Postgraduate School is to increase the combat effectiveness of U.S. and Allied armed forces and enhance the security of the USA through advanced education and research programs focused on the technical, analytical, and managerial tools needed to confront defense-related challenges.

CONTENTS

PREFACE

Research at the Naval Postgraduate School is carried out by faculty in the School's eleven academic departments, seven interdisciplinary groups, and the School of Aviation Safety. This volume contains research summaries for the projects undertaken by faculty in the Department of Operations Research during 1998. Also included is an overview of the department, faculty listing, a compilation of publications/presentations, and abstracts from theses directed by the department faculty.

Questions about particular projects may be directed to the faculty Principal Investigator listed, the Department Chair, or the Department Associate Chair for Research. Questions may also be directed to the Office of the Associate Provost and Dean of Research. General questions about the NPS Research Program should be directed to the Office of the Associate Provost and Dean of Research at (831) 656-2099 (voice) or research@nps.navy.mil (e-mail). Additional information is also available at the RESEARCH AT NPS website, http://web.nps.navy.mil~code09/.

INTRODUCTION

The research program at the Naval Postgraduate School exits to support the graduate education of our students. It does so by providing militarily relevant thesis topics that address issues from the current needs of the Fleet and Joint Forces to the science and technology that is required to sustain the long-term superiority of the Navy/DoD. It keeps our faculty current on Navy/DoD issues, permitting them to maintain the content of the upper division courses at the cutting edge of their disciplines. At the same time, the students and faculty together provide a very unique capability within the DoD for addressing warfighting problems. This capability is especially important at the present time when technology in general, and information operations in particular, are changing rapidly. Our officers must be able to think innovatively and have the knowledge and skills that will let them apply technologies that are being rapidly developed in both the commercial and military sectors. Their unique knowledge of the operational Navy, when combined with a challenging thesis project that requires them to apply their focussed graduate education, is one of the most effective methods for both solving Fleet problems and instilling the life-long capability for applying basic principles to the creative solution of complex problems.

The research program at NPS consists of both reimbursable (sponsored) and institutionally funded research. The research varies from very fundamental to very applied, from unclassified to all levels of classification.

- Reimbursable (Sponsored) Program: This program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policymakers throughout the Navy, DoD, and other government agencies as well as with the private sector in defense-related technologies. The sponsored program utilizes Cooperative Research and Development Agreements (CRADAs) with private industry, participates in consortia with other government laboratories and universities, provides off-campus courses either on-site at the recipient command or by VTC, and provides short courses for technology updates.

- NPS Institutionally Funded Research Program (NIFR): The institutionally funded research program has several purposes: (1) to provide the initial support required for new faculty to establish a Navy/DoD relevant research area, (2) to provide support for major new initiatives that address near-term Fleet and OPNAV needs, (3) to enhance productive research that is reimbursable sponsored, (4) to contribute to the recapitalization of major scientific equipment, and (5) to cost-share the support of a strong post-doctoral program.

- Institute for Joint Warfare Analysis (IJWA) Program: The IJWA Program provides funding to stimulate innovative research ideas with a strong emphasis on joint, interdisciplinary areas. This funding ensures that joint relevance is a consideration of research faculty.

In 1998, the overall level of research effort at NPS was 145 faculty workyears and exceeded $35 million. The Department of Operations Research's effort was 11.89 faculty workyears and exceeded $2.1 million. The sponsored research program has grown steadily to provide the faculty and staff support that is required to sustain a strong and viable graduate school in times of reduced budgets. In FY98, over 81% percent of the NPS research program was externally supported. In the Department of Operations Research 85% was externally supported.

The department's research sponsorship in FY98 is provided in Figure 1.
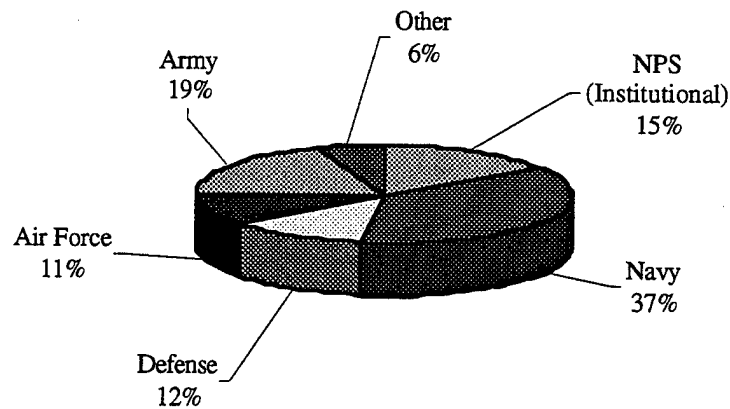
Figure 1. FY98 Sponsor Profile of the Department of Operations Research

These are both challenging and exciting times at NPS and the research program exists to help ensure that we remain unique in our ability to provide graduate education for the warfighter.

DAVID W. NETZER
Associate Provost and Dean of Research

October 1999

FACULTY LISTING

Rosenthal, Richard E.
Professor and Chair
831-656-2381 (phone)
831-656-2595 (fax)
rosenthal@nps.navy.mil

Brown, Gerald
Professor and Associate Chair for Research
OR/Bw
831-656-2140
gbrown@nps.navy.mil

Anderson, Timothy P., LCDR, USN
Military Instructor
OR/At
831-656-3583
tpanderson@nps.navy.mil

Eagle, James D.
Professor
OR/Er
831-656-2654
jeagle@nps.navy.mil

Hughes, Wayne P.
Senior Lecturer
OR/Hi
831-656-2484
whughes@nps.navy.mil

Bradley, Gordon H.
Professor
OR/Bz
831-656-2359
bradley@nps.navy.mil

Esary, James D.
Professor Emeritus
OR/Ey
831-656-2780
jdesary@nps.navy.mil

Jacobs, Patricia A.
Professor
OR/Jc
831-656-2258
pajacobs@nps.navy.mil

Buss, Arnold
Assistant Professor
OR/Bu
831-656-3259
abuss@nps.navy.mil

Gaver, Donald P.
Distinguished Professor
OR/Gv
831-656-2605
dgaver@nps.navy.mil

Kemple, William G.
Associate Professor
OR/Ke
831-656-3309
kemple@nps.navy.mil

Buttrey, Samuel E.
Assistant Professor
OR/Sb
831-656-3035
buttrey@nps.navy.mil

Halwachs, Thomas E.
Senior Lecturer
OR/Ha
831-656-2413
Halwachs@nps.navy.mil

Kerman, Mitchell C., LT, USN
Military Instructor
OR/Km
831-656-3452
mckerman@nps.navy.mil

Conner, George
Assistant Provost
OR/Co
831-656-3306
gconner@nps.navy.mil

Hoivik, Thomas H.
Senior Lecturer
OR/Ho
831-656-2040
thhoivik@nps.navy.mil

Koyak, Robert A.
Assistant Professor
OR/Kr
831-656-2688
rakoyak@nps.navy.mil

David, Israel
Visiting Associate Professor
OR/Di
831-656-3004
idavid@nps.navy.mil

Howard, Gilbert T.
Associate Professor
OR/Hk
831-656-3784
ghoward@nps.navy.mil

Krebs, William
Assistant Professor
OR/Kw
831-656-2543
wkrebs@nps.navy.mil

Dell, Robert F.
Associate Professor
OR/De
831-656-2853
dell@nps.navy.mil

Hozaki, Ryusuke
Visiting Professor
OR/Hr
831-656-2191
rhozaki@nps.navy.mil

Larson, Harold J.
Professor
OR/La
831-656-2473
hlarson@navy.mil

Lawphongpanich, Siriphong
Associate Professor
OR/Lp
831-656-2106
slawphon@nps.navy.mil

Lewis, Peter A.W.
Distinguished Professor
OR/Lw
831-656-2283
plewis@nps.navy.mil

Lucas, Tom
Associate Professor
OR/Lt
831-656-3039
twlucas@nps.navy.mil

Mackinnon, Douglas J., LCDR, USN
Military Instructor
OR/Mg
831-656-2085
djmackin@nps.navy.mil

Maher, Kevin J., CDR, USN
Military Instructor
OR/Mk
831-656-2691
kjmaher@nps.navy.mil

Marshall, Kneale T.
Distinguished Professor
OR/Mt
831-656-2474
kmarshall@nps.navy.mil

McGinnis, Michael, LTC, USA
Assistant Professor
831-656-3086
mcginnism@trac.nps.navy.mil

Milch, Paul R.
Professor
OR/Mh
831-656-2882
pmilch@nps.navy.mil

Nakagawa, Gordon R.
Lecturer
OR/Na
831-656-2303
gnakagawa@nps.navy.mil

Newman, Alexandra
Research Assistant Professor
OR/Nl
831-656-3113
amnewman@nps.navy.mil

Parker, Joel R., LTC, USA
Military Instructor
OR/Jp
831-656-2636
jrparker@nps.navy.mil

Parry, Sam H.
Professor
OR/Py
831-656-2779
shparry@nps.navy.mil

Powell, James R., CAPT, USN
Military Instructor
OR
831-656-2203
jrpowell@nps.navy.mil

Purdue, Peter
Professor
OR/Pd
831-656-2381/2663
ppurdue@nps.navy.mil

Read, Robert R.
Professor
OR/Re
831-656-2382
rread@nps.navy.mil

Sanchez, Paul
Visiting Professor
OR/Sp
831-656-3003
pjsanche@nps.navy.mil

Schmidt, John K., CDR, USN
Assistant Professor
Code 10
831-656-2581
jkschmidt@nps.navy.mil

Schrady, David
Distinguished Professor
OR/So
831-656-2801
dschrady@nps.navy.mil

Shaw, Charles H., LTC, USA
Military Instructor
OR/Sc
831-656-2636
chshaw@nps.navy.mil

Sovereign, Michael G.
Professor
OR/Sm
831-656-3008
msovereign@nps.navy.mil

Taylor, James G.
Professor
OR/Tw
831-656-2683
jtaylor@nps.navy.mil

Washburn, Alan R.
Professor
OR/Ws
831-656-3127
awashburn@nps.navy.mil

Whitaker, Lyn R.
Associate Professor
OR/Wh
831-656-3482
lwhitaker@nps.navy.mil

Williams, Laura M.
Research Assistant Professor
(501) 605-0682
lmwilliams@nps.navy.mil

Zehna, Peter
Professor Emeritus
OR/Ze
831-656-2653
pzehna@nps.navy.mil

DEPARTMENT SUMMARY

The research program in the Department of Operations Research seeks to advance the state of knowledge in key technology areas important to the Department of the Navy, Department of Defense, and military planning.

Research is evaluated by three criteria, namely, scholarship, relevance, and educational value:

- Scholarship is demonstrated by written research papers that appear in the open literature after peer review by experts in the field. Products of scholarship also include technical reports, student theses, reports to sponsors and conference presentations. (All graduate faculty have a PhD or equivalent.)

- Relevance is evident when sponsors are willing to underwrite the cost of research. Research gains additional relevance when sponsors or their clients use our research results; we expect this to happen frequently.

- Education is our primary mission and our research assists in that mission. All graduate faculty are expected to perform research in the areas in which they instruct. These faculty are at the forefront of their research areas, so they can instruct at the forefront of education, too.

Research Mission Statement of the Operations Research Department

Traditional basic research areas in the Operations Research Department include: (1) Optimization, (2) Probability and Stochastic Models, and (3) Statistics and Data Analysis. Related topics are also pursued, including (4) Human Systems Integration, (5) Search, Detection, and Evasion, (5) Games, Tactics, and Strategy, and (7) War Gaming and Simulation.

The Operations Research Department operates a number of research laboratories:

Human Systems Integration Lab, Gl 221 (3,080sf):
  Computers, psychometric experimental equipment.
Learning Research Centers, Gl-128 (952sf), Gl-203 (1,080sf), Gl-318 (960sf)
  Networked PCs and servers,
  Video display projectors, and
  OR Departmental licensed software suite.
Optimization Lab, Gl-206 (288sf)
  An IBM RS-6000, networked PCs and servers, and support hardware,
  Commercial optimization software suites, and
  Topical thesis and publication library.
Operational Logistics Lab, Gl 274 (160sf)
  Development and use of TACLOG models, logistics exercises,
  NAVY TAC 3 computer, and
  Topical thesis and publication library.
Statistics Lab, Gl 221 (shared space)
  Computers, exploratory data analysis software.
Analysis and Simulation Lab, Gl 286 (600sf)
  Unix workstations, graphical displays, software.
Secure Computing and Simulation Lab, In 157 (3,400sf)
  Classified wargame facility, and
  Sun SpARCstations, Silicon Graphics workstations, PC network.

The Operations Research Department also uses other research laboratories and equipment on campus by agreement with their managers, and uses classified research spaces.

DEPARTMENT SUMMARY

The following summaries demonstrate the breadth and depth of the unclassified research program in the Department of Operations Research. Summaries of the classified research programs are available via appropriate authority.

PAN ARCHITECTURE FOR DYNAMIC PLANNING SYSTEMS
USING LOOSELY COUPLED COMPONENTS

Gordon H. Bradley, Professor
Arnold H. Buss, Visiting Assistant Professor
Department of Operations Research
Sponsor: Air Force Office of Scientific Research

OBJECTIVE: To design and develop an architecture for dynamic map-based military planning applications using new platform-independent software technology. This is a continuing research project.

SUMMARY: The research has designed and developed a "loosely coupled components" architecture that has been demonstrated by constructing a map-based planning system for dynamic military planning. The architecture coordinates a collection of components that operate over heterogeneous computer networks. The system accesses and displays data, maps, overlays, algorithms, and other information. The components perform tasks such as: displaying maps, satellite images, and overlays; accessing, entering, and modifying data; constructing and displaying models of military operations; and accessing and executing algorithms to analyze operations. The design allows systems to be easily extended by adding additional components.

PUBLICATIONS:

Bradley, G. and Buss, A., "Dynamic, Distributed, Platform Independent OR/MS Applications-A Network Perspective," *INFORMS Journal on Computing*, Vol. 10, No. 4, pp. 384-387, Fall 1998.

Buss, A. and Jackson, L., "Distributed Simulation Modeling: A Comparison of HLA, CORBA, and RMI," *Proceedings of the 1998 Winter Simulation Conference*, pp. 819-825, Washington, DC, December 1998.

Buttrey, S. and Bradley, G., "Dynamic, Interactive Statistical Research Papers on the Web," *Proceedings of the Statistical Computing Section of the American Statistical Association*, pp. 1-6, Anaheim, CA, 1997.

Page, E., Buss, A.P., Fishwick, K., Healy, R., Nance, R., and Paul, R., "The Modeling Methodological Impacts of Web-Based Simulation," *Proceedings of the 1998 International Conference on Web-Based Modeling and Simulation*, January 1998.

CONFERENCE PRESENTATIONS:

Bradley, G., "Architecture for Dynamic Map-Based Military Planning Systems Using Platform Independent Software Technologies," 2nd Center for Military Analysis/Naval Postgraduate School Meeting, Haifa, Israel, 2 July 1998.

Bradley, G., "Map-Based Dynamic Planning Systems in Java," INFORMS International, Tel Aviv, Israel, 28 June-1 July 1998.

Bradley, G., Buss, A., Bilyeu, A, and Jackson, L., "Demonstration: Platform Independent, Distributed, Dynamic, Map-Based Military Planning Systems," 66th Military Operations Research Society Symposium, Monterey, CA, 23 -25 June 1998.

Bradley, G., Buss, A., Bilyeu, A., and Arntzen, A., "Loosely Coupled Components - Architecture for Dynamic Map-Based Military Planning Systems Using Platform Independent Software Technologies," Air Force Office of Scientific Research - New World Vistas Project Review, Monterey, CA, 5 May 1998.

Bradley, G., Buss, A., and Shaw, C.H., III, "Loosely Coupled Components - Architecture for Dynamic Map-Based Military Planning, Analysis, Rehearsal, and Execution Systems Using Platform Independent Software Technologies," MPARE IPT Conference, USSOCOM, MacDill AFB, Tampa, FL, 10-14 August 1998.

Bradley, G., "Tutorial: Java Introduction and OR Applications," 6th INFORMS Computer Science Technical Section Conference on Computer Science and Operations Research: Recent Advances in the Interface, Monterey, CA, 7-9 January 1998.

Buss, A. and Jackson, L., "Distributed Simulation Modeling: A Comparison of HLA, CORBA, and RMI," 1998 Winter Simulation Conference, Washington DC, 13-16 December 1998.

Page, E., Buss, A., Fishwick, P., Healy, K., Nance, R., and Paul, R., "The Modeling Methodological Impacts of Web-Based Simulation," 1998 International Conference on Web-Based Modeling and Simulation, 11-14 January 1998.

THESES DIRECTED:

Arntzen, Arent, "Software Components for Air Defense Planning," Master's Thesis, Naval Postgraduate School, September 1998.

Bilyeu, Allan L., "Concept for a Special Operations Planning and Analysis System," Master's Thesis, Naval Postgraduate School, June 1998.

Castle, Timothy S., "Coordinated Area Search and Rescue (SAR) Planning and Execution Tool," Master's Thesis, Naval Postgraduate School, September 1998.

Knight, Steven D., "A Comparison of Analysis in DIS and HLA," Master's Thesis, Naval Postgraduate, June 1998.

Ruck, John L., "An Object-Oriented Discrete-Event Simulation of Logistics (Modeling Focused Logistics)," Master's Thesis, Naval Postgraduate School, September 1998.

Schwartz, Victor S., "Dynamic Platform-Independent Meta-Algorithms for Graph-Partitioning," Master's Thesis, Naval Postgraduate School, September 1998.

OTHER:

SOFLCC: A system to support real-time and near real-time decision-making for Special Operations Forces using network models based on the Loosely Coupled Components Architecture (LCCA).

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications, Computing and Software, Modeling and Simulation, Other (Decision Support Systems)

KEYWORDS: Dynamic Planning, Loosely Coupled Components, Platform Independent Software, Java

FUTURE TECHNOLOGIES FOR SPECIAL OPERATIONS MISSION PLANNING, ANALYSIS, REHEARSAL, AND EXECUTION (MPARE)
Gordon H. Bradley, Professor
Arnold H. Buss, Visiting Assistant Professor
LTC Charles H. Shaw, III, USA, Military Instructor
Department of Operations Research
Sponsor: U.S. Special Operations Command

OBJECTIVE: To research and analyze emerging and leap-ahead technologies in support of USSOCOM in the requirements stage for its Mission Planning, Analysis, Rehearsal, and Execution (MPARE) initiative and to advise and support on technology trends and future technology capabilities in C4I.

PROJECT SUMMARIES

SUMMARY: The research has analyzed the use of platform independent, dynamic, distributed hardware, and software systems to support Special Forces mission planning and execution. Capabilities have been shown with a technology demonstration system for map-based planning. The future technology section of the MPARE CONOPS was developed.

PUBLICATIONS:

Buss, A. and Jackson, L., "Distributed Simulation Modeling: A Comparison of HLA, CORBA, and RMI," *Proceedings of the 1998 Winter Simulation Conference,* Washington, DC, pp. 819-825, December 1998.

Page, E., Buss, A., Fishwick, P., Healy, K., Nance, R., and Paul, R., "The Modeling Methodological Impacts of Web-Based Simulation," *Proceedings of the 1998 International Conference on Web-Based Modeling & Simulation,* January 1998.

Shaw, Charles H., III, "Overview of SOF Modeling and Analysis in Support of the U.S. Special Operations Command (USSOCOM)," *Proceedings of the 66th Military Operations Research Society Symposium*, pp. 159, Monterey, CA, June 1998.

CONFERENCE PRESENTATIONS:

Bilyeu, A. and Shaw, C.H., III, "Platform Independent, Distributed, Dynamic, Map-Based Military Planning and Analysis Systems for SOF," 66th Military Operations Research Society Symposium, Monterey CA, 23-25 June 1998.

Bradley, G., "Architecture for Dynamic Map-Based Military Planning Systems Using Platform Independent Software Technologies," 2nd Center for Military Analysis/Naval Postgraduate School Meeting, Haifa, Israel, 2 July 1998.

Bradley, G., "Map-Based Dynamic Planning Systems in Java," INFORMS International, Tel Aviv, Israel, 28 June-1 July 1998.

Bradley, G., Buss, A., and Shaw, C.H., III, "Loosely Coupled Components - Architecture for Dynamic Map-Based Military Planning, Analysis, Rehearsal, and Execution Systems Using Platform Independent Software Technologies," MPARE IPT Conference, Tampa, FL, 10-14 August 1998.

Bradley, G., Buss, A., Bilyeu, A., and Jackson, L., "Demonstration: Platform Independent, Distributed, Dynamic, Map-Based Military Planning Systems," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

Buss, A. and Jackson, L., "Distributed Simulation Modeling: A Comparison of HLA, CORBA, and RMI," 1998 Winter Simulation Conference, Washington, DC, 13-16 December 1998.

Lanquist, T. and Shaw, C.H., III, "Logistics Planning Factors for Special Operations Forces (SOF) Logistics Modeling and Simulation," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

Page, E., Buss, A.P., Fishwick, K., Healy, K., Nance, R., and Paul, R., "The Modeling Methodological Impacts of Web-Based Simulation," 1998 International Conference on Web-Based Modeling and Simulation, 11-14 January 1998.

Shaw, C.H., III, "Map-Based Dynamic Planning and Analysis Using Java and CORBA," Joint Mission Analysis (JMA) and MPARE Integrated Product Team (IPT) Conference, Tampa, FL, 2-6 February 1998.

Shaw, C.H., III, "Overview of SOF Modeling and Analysis in Support of the U.S. Special Operations Command (USSOCOM)," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

Shaw, C.H., III, "Modeling Logistics in Full Spectrum Operations/Operations Other Than War (FSO/OOTW)," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

THESES DIRECTED:

Arntzen, Arent, "Software Components for Air Defense Planning," Master's Thesis, Naval Postgraduate School, September 1998.

Knight, Steven D., "A Comparison of Analysis in DIS and HLA," Master's Thesis, Naval Postgraduate, June 1998.

Lanquist, Timothy S., "Army Special Operations Forces Logistics Planning Aid," Master's Thesis, Naval Postgraduate School, September 1998.

Olson, Keith E., "Analyzing Sensor-Shooter Links through Simulation," Master's Thesis, Naval Postgraduate School, June 1998.

Ruck, John L., "An Object-Oriented Discrete-Event Simulation of Logistics (Modeling Focused Logistics)," Master's Thesis, Naval Postgraduate School, September 1998.

Wagner, Brett A., "Air Force Special Operation Forces Logistics Planning Aid," Master's Thesis, Naval Postgraduate School, September 1998.

OTHER:

SOFLCC: A system to support real-time and near real-time decision-making for Special Operations Forces using network models based on the Loosely Coupled Components Architecture (LCCA).

SOFLOGPLNR Software Programs

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications, Computing and Software, Modeling and Simulation, Other (Decision Support Systems)

KEYWORDS: Dynamic Planning, Loosely Coupled Components, Platform Independent Software, Java

PLATFORM-INDEPENDENT, DISTRIBUTED MAP-BASED DYNAMIC MILITARY PLANNING FOR JOINT SPECIAL FORCES OPERATIONS
Gordon H. Bradley, Professor
LTC Charles H. Shaw, III, USA, Military Instructor
Department of Operations Research
Sponsor: Naval Postgraduate School

OBJECTIVE: Support ongoing research designing and developing an architecture for dynamic map-based planning applications using new platform independent software technology.

SUMMARY: The research has analyzed the use of platform independent, dynamic, distributed hardware and software systems to support Special Forces mission planning and execution. The research has designed and developed a technology demonstration system for a map-based planning system for dynamic military planning. The architecture coordinates a collection of components that operate over heterogeneous computer networks. The system accesses and displays data, maps, overlays, algorithms, and other information. The components perform tasks such as: displaying maps, satellite images, and overlays; accessing, entering, and modifying data; constructing and displaying models of military operations; and accessing and executing algorithms to analyze operations. The design allows systems to be easily extended by adding additional components. In addition, Logistics Planning Factors for SOF unique units and operations were researched and derived for use in support planning.

PROJECT SUMMARIES

PUBLICATION:

Shaw, Charles H., III, "Overview of SOF Modeling and Analysis in Support of the U.S. Special Operations Command (USSOCOM)," *Proceedings of the 66th Military Operations Research Society Symposium*, pp. 159, Monterey, CA, June 1998.

CONFERENCE PRESENTATIONS:

Bilyeu, A. and Shaw, C.H., III, "Platform Independent, Distributed, Dynamic, Map-Based Military Planning and Analysis Systems for SOF," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

Bradley, G., "Architecture for Dynamic Map-Based Military Planning Systems Using Platform Independent Software Technologies," 2nd Center for Military Analysis/Naval Postgraduate School Meeting, Haifa, Israel, 2 July 1998.

Bradley, G., "Map-Based Dynamic Planning Systems in Java," INFORMS International, Tel Aviv, Israel, 28 June-1 July 1998.

Bradley, G., Buss, A., Bilyeu, A., and Jackson, L., "Demonstration: Platform Independent, Distributed, Dynamic, Map-Based Military Planning Systems," 66th Military Operations Research Society Symposium, Monterey, CA, 23 -25 June 1998.

Bradley, G., Buss, A., and Shaw, C.H., III, "Loosely Coupled Components - Architecture for Dynamic Map-Based Military Planning, Analysis, Rehearsal, and Execution Systems Using Platform Independent Software Technologies," MPARE IPT Conference, Tampa, FL, 10-14 August 1998.

Lanquist, T. and Shaw, C.H., III, "Logistics Planning Factors for Special Operations Forces (SOF) Logistics Modeling and Simulation," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

Shaw, C.H., III, "Map-Based Dynamic Planning and Analysis Using Java and CORBA," Joint Mission Analysis (JMA) and MPARE Integrated Product Team (IPT) Conference, Tampa, FL, 2-6 February 1998.

Shaw, C.H., III, "Overview of SOF Modeling and Analysis in Support of the U.S. Special Operations Command (USSOCOM)," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

Shaw, C.H., III, "Modeling Logistics in Full Spectrum Operations/Operations Other Than War (FSO/OOTW)," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

THESES DIRECTED:

Bilyeu, Allan L., "Concept for a Special Operations Planning and Analysis System," Master's Thesis, Naval Postgraduate School, June 1998.

Castle, Timothy S., "Coordinated Area Search and Rescue (SAR) Planning and Execution Tool," Master's Thesis, Naval Postgraduate School, September 1998.

Lanquist, Timothy S., "Army Special Operations Forces Logistics Planning Aid," Master's Thesis, Naval Postgraduate School, September 1998.

Olson, Keith E., "Analyzing Sensor-Shooter Links Through Simulation," Master's Thesis, Naval Postgraduate School, June 1998.

Wagner, Brett A., "Air Force Special Operation Forces Logistics Planning Aid," Master's Thesis, Naval Postgraduate School, September 1998.

OTHER:

Software deliverables to the United States Special Operations Command (USSOCOM) included the Special Operations Forces Logistics Planner (SOFLOGPLNR) programs for each Service component and the Special Operations Forces Loosely Coupled Components Planning and Analysis Program (SOFLCC Program).

SOFLOGPLNR is a set of three software programs to support real-time logistics estimation and support planning for SOF using an MS Windows and Visual Basic Graphical User Interface (GUI) and Logistics Planning Factors specific to SOF in an Excel Spreadsheet.

SOFLCC is a system to support real-time and near real-time decision-making for SOF using network models based on the Loosely Coupled Components Architecture (LCCA).

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications, Computing and Software, Modeling and Simulation, Other (Decision Support Systems)

KEYWORDS: Dynamic Planning, Loosely Coupled Components, Platform Independent Software, Java

LARGE-SCALE OPTIMIZATION
Gordon H. Bradley, Professor
Gerald G. Brown, Professor
R. Kevin Wood, Professor
Department of Operations Research
Sponsors: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: To use large-scale mathematical programming techniques to solve deterministic and stochastic extensions of important combinatorial optimization models and develop graph and network algorithms for dynamic map-based military planning applications. This is a continuing research project.

SUMMARY: One part of this research designed and developed a toolkit of methods to quickly construct graph and network algorithms. The algorithms were integrated into a dynamic map-based military planning system that operates over heterogeneous computer networks. The system can download algorithms over a computer network and execute them to analyze operations. The design allows algorithms to be easily added to the planning system. Another part of this research developed new Monte Carlo methods for evaluating the accuracy of solutions to stochastic programming models. We have also developed a new class of simplicial penalties applicable in lieu of polyhedral cuts to encourage admissable integer polyhedral solutions.

PUBLICATIONS:

Appleget, J. and Wood, K., "Explicit-Constraint Branching for Solving Mixed-Integer Programs," in review.

Bradley, G. and Buss, A., "Dynamic, Distributed, Platform Independent OR/MS Applications—A Network Perspective," *INFORMS Journal on Computing*, 10, pp. 384-387, 1998.

Brown, G., Bausch, D., and Ronen, D., "Scheduling Short-Term Marine Transport of Bulk Products," *Maritime Policy and Management*, 25-4, pp. 335-348, 1998.

Brown, G., Dell, R., and Olson, M., "Valid Integer Polytope (VIP) Penalties for Branch-and-Bound Enumeration," in review.

Cormican, K., Morton, D., and Wood, K., "Stochastic Network Interdiction," *Operations Research*, 46, pp. 184-197, 1998.

Kerman, C.K., Brown, G., and Dell, R., "Optimally Reorganizing Navy Shore Infrastructure," Naval Postgraduate School Technical Report, NPS-OR-98-006, August 1998.

Morton, D., Mak, W., and Wood, K., "Monte Carlo Bounding Techniques for Verifying Solution Quality in Stochastic Programs," *OR Letters*, to appear.

Morton, D. and Wood, K., "Restricted-Recourse Bounds for Stochastic Linear Programming," *Operations Research*, to appear.

Morton D. and Wood, K., "A Class of Optimistic Monte Carlo Bounds for Stochastic Programming," in review.

Morton, D. and Wood, K., "On a Stochastic Knapsack Problem and Generalizations," *Advances in Computational and Stochastic Optimization, Logic Programming, and Heuristic Search: Interfaces in Computer Science and Operations Research*, D.L. Woodruff, (ed.), pp. 149-168, 1998.

Newman, A., Brown, G., Dell, R., Giddings, A., and Rosenthal, R., "Planning Procurement and Deployment of Space and Missile Assets," forthcoming.

CONFERENCE PRESENTATIONS:

Bradley, G., "Architecture for Dynamic Map-Based Military Planning Systems Using Platform Independent Software Technologies," 2nd Center of Military Analysis/Naval Postgraduate School Meeting, Haifa, Israel, 2 July 1998.

Bradley, G., "Map-Based Dynamic Planning Systems in Java," INFORMS International, Tel Aviv, Israel, 28 June-1 July 1998.

Bradley, G., Buss, A., Bilyeu, A., and Jackson, L., "Demonstration: Platform Independent, Distributed, Dynamic, Map-Based Military Planning Systems," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

Bradley, G., Buss, A., Bilyeu, A., and Arntzen, A., "Loosely Coupled Components - Architecture for Dynamic Map-Based Military Planning Systems Using Platform Independent Software Technologies," Air Force Office of Scientific Research - New World Vistas Project Review, Monterey, CA, 5 May 1998.

Bradley, G., "Tutorial: Java Introduction and OR Applications," 6th INFORMS Computer Science Technical Section Conference on Computer Science and Operations Research: Recent Advances in the Interface, Monterey, CA, 7-9 January 1998.

Bradley, G., Buss, A. and Shaw, C.H., III, "Loosely Coupled Components - Architecture for Dynamic Map-Based Military Planning, Analysis, Rehearsal, and Execution Systems Using Platform Independent Software Technologies," MPARE IPT Conference, USSOCOM, MacDill AFB, Tampa, FL, 10-14 August 1998.

Curet, Norman D., Brandeau, John F., and Olson, A., "An Integer Programming Formulation for Estimating Hierarchical Levels in an Undirected Graph," CORS/INFORMS, Montreal, Canada, 28 April 1998.

Israeli, E. and Wood, K., "Maximizing a Shortest Path," INFORMS National Meeting, Seattle, WA, 25-28 October 1998.

Morton, D. and Wood, K., "Optimistic Bounds for Stochastic Optimization," Prague Stochastics 98, Charles University, Prague, Czech Republic, 23-28 August 1998.

Morton, D. and Wood, K., "Optimistic Monte Carlo Bounds for Stochastic Programming," VII International Conference on Stochastic Programming, Vancouver, BC, Canada, 8-16 August 1998.

Morton, D. and Wood, K., "On a Stochastic Knapsack Problem and Generalizations," 6th INFORMS Computer Science Technical Section Conference, Monterey, CA, 6-9 January 1998.

THESES DIRECTED:

Albright, Michael H., "An Optimization-Based Decision Support Model for the Navy H-60 Helicopter Preventive Maintenance Program," Master's Thesis, Naval Postgraduate School, September 1998.

Ayik, Mehmet, "Optimal Long-Term Aircraft Carrier Deployment Planning with Synchronous Depot Level Maintenance Scheduling," Master's Thesis, Naval Postgraduate School, March 1998.

Bilyeu, Allan L., "Concept for a Special Operations Planning and Analysis System," Master's Thesis, Naval Postgraduate School, June 1998.

Boyle, Michael R., "Partial-Enumeration for Planar Network Interdiction Problems," Master's Thesis, Naval Postgraduate School, March 1998.

Castle, Timothy S., "Coordinated Area Search and Rescue (SAR) Planning and Execution Tool," Master's Thesis, Naval Postgraduate School, September 1998.

Olson, Allen S., "Classifying PSTN Switching Stations: A National Security Agency Application," Master's Thesis, Naval Postgraduate School, September 1998.

Schwartz, Victor S., "Dynamic Platform-Independent Meta-Algorithms for Graph-Partitioning," Master's Thesis, Naval Postgraduate School, September 1998.

Theres, Michael J., "Models for Comparing Air-Only and Sea/Air Transportation of Wartime Deployment Cargo," Master's Thesis, Naval Postgraduate School, September 1998.

Tivnan, Brian F., "Optimizing United States Marine Corps Enlisted Assignments," Master's Thesis, Naval Postgraduate School, September 1998.

Viado, Harold A., "An Optimization Model of Class III (Bulk Fuel) Supply for a Deployed MEU (SOC) through Sea-Based Logistics," Master's Thesis, Naval Postgraduate School, September 1998.

Yost, Kirk A., "Solution of Large-Scale Allocation Problems with Partially Observable Outcomes," Dissertation, Naval Postgraduate School, September 1998.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Other (Decision Support Systems)

KEYWORDS: Integer Programming, Stochastic Programming, Dynamic Planning

PROJECT SUMMARIES

LARGE-SCALE OPTIMIZATION
Gerald G. Brown, Professor
R. Kevin Wood, Professor
Department of Operations Research
Sponsor: Air Force Office of Scientific Research

OBJECTIVE: Use large-scale mathematical programming techniques to solve deterministic and stochastic extensions of important combinatorial optimization models. Develop new shortest-path network-interdiction techniques and extensions.

SUMMARY: This research developed new Monte Carlo methods for evaluating the accuracy of solutions to stochastic programming models and developed new deterministic bounds for stochastic programs. We have also developed a new class of simplicial penalties applicable in lieu of polyhedral cuts to encourage admissable integer polyhedral solutions. Additionally, we have developed new network-interdiction models and solution techniques that readily generalize to more complicated system models.

PUBLICATIONS:

Appleget, J. and Wood, K., "Explicit-Constraint Branching for Solving Mixed-Integer Programs," in review.

Brown, G., Bausch, D., and Ronen, D., "Scheduling Short-Term Marine Transport of Bulk Products," *Maritime Policy and Management*, 25-4, pp. 335-348, 1998.

Brown, G., Dell, R., and Olson, M., "Valid Integer Polytope (VIP) Penalties for Branch-and-Bound Enumeration," in review.

Cormican, K., Morton, D., and Wood, K., "Stochastic Network Interdiction," *Operations Research*, 46, pp. 184-197, 1998.

Israeli, E. and Wood, K., "Shortest-Path Network Interdiction," forthcoming.

Kerman C.K., Brown, G., and Dell, R., "Optimally Reorganizing Navy Shore Infrastructure," Naval Postgraduate School Technical Report, NPS-OR-98-006, August 1998.

Morton, D., Mak, W., and Wood, K., "Monte Carlo Bounding Techniques for Verifying Solution Quality in Stochastic Programs," *OR Letters*, to appear.

Morton, D. and Wood, K., "Restricted-Recourse Bounds for Stochastic Linear Programming," *Operations Research*, to appear.

Morton D. and Wood, K., "A Class of Optimistic Monte Carol Bounds for Stochastic Programming," in review.

Morton, D. and Wood, K., "On a Stochastic Knapsack Problem and Generalizations," *Advances in Computational and Stochastic Optimization, Logic Programming, and Heuristic Search: Interfaces in Computer Science and Operations Research*, D.L. Woodruff, (ed.), pp. 149-168, 1998.

Newman, A., Brown, G., Dell, R., Giddings, A., and Rosenthal, R., "Planning Procurement and Deployment of Space and Missile Assets," forthcoming.

CONFERENCE PRESENTATIONS:

Curet, Norman D., Brandeau, John F., and Olson, A., "An Integer Programming Formulation for Estimating Hierarchical Levels in an Undirected Graph," CORS/INFORMS, Montreal, Canada, 28 April 1998.

Israeli, E. and Wood, K., "Maximizing a Shortest Path," INFORMS National Meeting, Seattle, WA, 25-28 October 1998.

Morton, D. and Wood, K., "Optimistic Bounds for Stochastic Optimization," Prague Stochastics 98, Prague, Czech Republic, 23-28 August 1998.

Morton, D. and Wood, K., "Optimistic Monte Carlo Bounds for Stochastic Programming," VII International Conference on Stochastic Programming, Vancouver, BC, Canada, 8-16 August 1998.

Morton, D. and Wood, K., "On a Stochastic Knapsack Problem and Generalizations," 6th INFORMS Computer Science Technical Section Conference, Monterey, CA, 6-9 January 1998.

THESES DIRECTED:

Albright, Michael H., "An Optimization-Based Decision Support Model for the Navy H-60 Helicopter Preventive Maintenance Program," Master's Thesis, Naval Postgraduate School, September 1998.

Ayik, Mehmet, "Optimal Long-Term Aircraft Carrier Deployment Planning with Synchronous Depot Level Maintenance Scheduling," Master's Thesis, Naval Postgraduate School, March 1998.

Boyle, Michael R., "Partial-Enumeration for Planar Network Interdiction Problems," Master's Thesis, Naval Postgraduate School, March 1998.

Olson, Allen S., "Classifying PSTN Switching Stations: A National Security Agency Application," Master's Thesis, Naval Postgraduate School, September 1998.

Theres, Michael J., "Models for Comparing Air-Only and Sea/Air Transportation of Wartime Deployment Cargo," Master's Thesis, Naval Postgraduate School, September 1998.

Tivnan, Brian F., "Optimizing United States Marine Corps Enlisted Assignments," Master's Thesis, Naval Postgraduate School, September 1998.

Viado, Harold A., "An Optimization Model of Class III (Bulk Fuel) Supply for a Deployed MEU (SOC) Through Sea-Based Logistics," Master's Thesis, September 1998.

Yost, Kirk A., "Solution of Large-Scale Allocation Problems with Partially Observable Outcomes," Dissertation, Naval Postgraduate School, September 1998.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Computing and Software, Other (Decision Support Systems)

KEYWORDS: Integer Programming, Stochastic Programming

SUPPORT FOR THE CENTER FOR OPERATIONS RESEARCH, NATIONAL SECURITY AGENCY
Gerald G. Brown, Professor
Department of Operations Research
Sponsor: National Security Agency

OBJECTIVE: To provide on-call analytical support to the National Security Agency.

SUMMARY: Available from sponsor.

PUBLICATION:

Newman, A., Brown, G., Dell, R., Giddings, A., and Rosenthal, R., "Planning Procurement and Deployment of Space and Missile Assets," forthcoming.

CONFERENCE PRESENTATION:

Curet, Norman D., Brandeau, John F., and Olson, A., "An Integer Programming Formulation for Estimating Hierarchical Levels in an Undirected Graph," CORS/INFORMS, Montreal, Canada, 28 April 1998.

THESES DIRECTED:

Brandeau, John F., "An Algorithm for Classifying PSTN Switching Stations," Master's Thesis, Naval Postgraduate School, September 1998.

Olson, Allen S., "Classifying PSTN Switching Stations: A National Security Agency Application," Master's Thesis, Naval Postgraduate School, September 1998.

Yost, Kirk A., "Solution of Large-Scale Allocation Problems with Partially Observable Outcomes," Dissertation, Naval Postgraduate School, 1998.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Other (Optimization and Decision Support)

KEYWORD: Optimization

CHAIR OF APPLIED SYSTEMS ANALYSIS
CDR Ronald L. Brown, USN, Military Instructor
Department of Operations Research
Sponsor: Chief of Naval Operations (N81)

OBJECTIVE: To provide a direct relationship between the Director, Assessment Division (N81) and the Superintendent of the Naval Postgraduate School and support activities designated in the joint Memorandum of Understanding between the Superintendent and N81.

SUMMARY: During the current year, funding was used for support of student and faculty travel required during thesis and research work, support of faculty course development and research, and support of hardware and software upgrades within the Operations Research Department.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Operations Research, Modeling and Simulation, Curriculum Development

COMPONENT-BASED SIMULATION METHODOLOGY
Arnold H. Buss, Visiting Assistant Professor
Department of Operations Research
Sponsor: Unfunded

OBJECTIVE: To develop an effective modeling methodology for formulating and analyzing simulation models with superior robustness and timeliness.

SUMMARY: Traditional simulation methodology provides power means to formulate models for situations intractable using any other approach. Unfortunately, simulations models can be extremely costly to implement and equally costly to maintain, debug, and analyze. This work is an ongoing attempt to remedy this situation by developing a component-based simulation approach grounded in sound methodology and implemented in a modern, platform-independent language.

PUBLICATIONS:

Bradley, G. and Buss, A., "Dynamic, Distributed, Platform Independent OR/MS Applications-A Network Perspective," *INFORMS Journal on Computing*, Vol. 10, No. 4, pp. 384-387, Fall 1998.

Buss, A. and Jackson, L., "Distributed Simulation Modeling: A Comparison of HLA, CORBA, and RMI," *Proceedings of the 1998 Winter Simulation Conference,* Washington, DC, pp. 819-825, December 1998.

CONFERENCE PRESENTATIONS:

Buss, A. and Jackson, L., "Distributed Simulation Modeling: A Comparison of HLA, CORBA, and RMI," 1998 Winter Simulation Conference, Washington, DC, 13-16 December 1998.

Page, E., Buss, A., Fishwick, P., Healy, K., Nance, R., and Paul, R., "The Modeling Methodological Impacts of Web-Based Simulation," 1998 International Conference on Web-Based Modeling and Simulation, 11-14 January 1998.

OTHER:

Simkit, a Java package for discrete-event simulation modeling.

THESES DIRECTED:

Arntzen, Arent, "Software Components for Air Defense Planning," Master's Thesis, Naval Postgraduate School, September 1998.

Ruck, John L., "An Object-Oriented Discrete-Event Simulation of Logistics (Modeling Focused Logistics)," Master's Thesis, Naval Postgraduate School, September 1998.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Computing and Software

KEYWORDS: Discrete Event Simulation Methodology, Component-Based Modeling, Modeling and Simulation

A HIGH LEVEL ARCHITECTURE (HLA) FEDERATE FOR
DATA COLLECTION AND ANALYSIS
Arnold H. Buss, Visiting Assistant Professor
Department of Operations Research
Sponsor: U.S. Army Training and Doctrine Analysis Command-Monterey

OBJECTIVE: To develop a prototype of an Analysis Federate for data collection and analysis under the High Level Architecture (HLA).

SUMMARY: The High Level Architecture (HLA) is an emerging standard for distributed Modeling and Simulation (M&S). Data collection under HLA can be problematic since the standard does not directly provide logging capabilities. The Analysis Federate will provide near real-time derived data management for federations running simulations under HLA and also allow for collection and exchange of such data after each distributed simulation session. This approach combines the best aspects of data logging and subscription and reduces data logging requirements during the simulation run. Analysis Feder-

ate services take the form of extensible, reusable objects that collect, process, and display data. The potential benefits of this work are significant since data collection is a universal requirement in simulation sessions. The implementation of future advanced distributed simulations including the CASTFOREM re-implementation, OneSAF, and JWARS will potentially benefit from this project.

THESIS DIRECTED:

Knight, Steven D., "A Comparison of Analysis in DIS and HLA," Master's Thesis, Naval Postgraduate School, June 1998.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Computing and Software

KEYWORDS: Analysis Federate, High Level Architecture (HLA), CASTFOREM Re-implementation, OneSAF, JWARS

OPTIMIZATION MODELS FOR INSTALLATION MANAGEMENT
Robert F. Dell, Associate Professor
Department of Operations Research
Sponsors: Army Base Realignment and Closure Office and Naval Postgraduate School

OBJECTIVE: To develop optimization models to assist with installation management.

SUMMARY: The investigator is providing research, support, and development of optimization models to assist the Army's Base Realignment and Closure Office (BRACO). There are three modeling efforts at different levels of development in 1998: (1) continued refinement to BRACAS (Base Realignment and Closure Action Scheduler), an optimization model developed by the investigator and used extensively by BRACO; (2) initial development of an optimization model to assist with allocation of installation operating budgets; and (3) initial development of an optimization model to assist with allocation of environmental clean-up budgets.

PUBLICATIONS:

Dell, R.F., "Optimizing Army Base Realignment and Closure," *Interfaces*, Vol. 28, No. 6, pp. 1-8, November/December 1998.

Kerman C.K., Brown, G.G., and Dell, R.F., "Optimally Reorganizing Navy Shore Infrastructure," Naval Postgraduate School Technical Report, NPS-OR-98-006, August 1998.

THESIS DIRECTED:

Chilson, C., "Minimizing Army Cadet Temporary Duty," Master's Thesis Naval Postgraduate School, March 1998.

DoD KEY TECHNOLOGY AREA: Other (Optimization)

KEYWORDS: BRAC, Capital Budgeting, Optimization, Mixed Linear Integer Programming Application

PROJECT SUMMARIES

INVESTIGATION INTO REPRESENTATIONS OF INTELLIGENCE, PERCEPTION AND UNCERTAINTY WITHIN OPERATIONAL DETERMINISTIC SIMULATIONS

Donald P. Gaver, Distinguished Professor
Patricia A. Jacobs, Professor
Department of Operations Research
Sponsor: U.S. Army Training and Doctrine Analysis Command-Monterey

OBJECTIVE: To develop a methodology for an operational perception that quantifies uncertainty and reflects information warfare.

SUMMARY: A search of the literature on human factors influencing decision making was conducted.

PUBLICATION:

Jacobs, P.A. and Gaver, D.P., "Human Factors Influencing Decision Making," Naval Postgraduate School Technical Report, NPS-OR-98-003, July 1998.

DoD KEY TECHNOLOGY AREA: Human-System Interface

KEYWORDS: Decision Making, Human Factors

RESEARCH IN JOINT WARFARE MODELING AND SIMULATION EMPHASIZING INFORMATION WARFARE ISSUES

Donald P. Gaver, Distinguished Professor
Patricia A. Jacobs, Professor
Department of Operations Research
Sponsors: Director, Operational Test and Evaluation, Naval Postgraduate School-Institute for Joint Warfare Analysis, and Strategic Planning Office (N6C3)

OBJECTIVE: The purpose of the research is to formulate and study state-space models for information operations in joint warfare, with a view towards guiding allocation of acquisition and eventually operational resources. The emphasis is on modeling the impact of information obtained from realistically imperfect sensor systems on interactive and joint conflicts.

SUMMARY: Models for the effect of Battle Damage Assessment (BDA) on targeting have been formulated and studied. The effect of various levels of sensor effort on combat has been and is being modeled in various scenarios. Models to assess the suitability of UAVs have been formulated and studied. Models for suppression of enemy air defense have been formulated and studied.

PUBLICATIONS:

Gaver, D.P., Jacobs, P.A., and Youngren, M.A., "Analytical Models for Battlespace Information War (BAT-IW) Part 1," Naval Postgraduate School Technical Report, NPS-OR-98-001, February 1998.

Gaver, D.P. and Jacobs, P.A. "Suppression of Enemy Air Defense (SEAD) as an Information Duel," Naval Postgraduate School Technical Report, NPS-OR-98-005, August 1998.

Gaver, D.P., Jacobs, P.A., and Stoneman, J., "Analytical Models for Mobile Sensor (UAV) Coverage of a Region," Naval Postgraduate School Institute for Joint Warfare Analysis Technical Report, May 1998.

Gaver, D.P., Jacobs, P.A., and Youngren, M.A., "Analytical Models for Battlespace Information War (BAT-IW) Part 2," forthcoming.

Gaver, D.P., Jacobs, P.A., and Youngren, M.A., "Binomial-like Sensors," in progress.

Gaver, D.P., Jacobs, P.A., Youngren, M.A., and Parry, S.H., "Models for Force Interaction that Involve Uncertain Perception," forthcoming.

Davis, D.S., "Basic Physics of Target Sensing for Joint Theater-Level Models of the Future," forthcoming.

Gaver, D.P. and Jacobs, P.A., "In Search of Military Unit Formations: G-String Models," forthcoming.

Gaver, D.P. and Jacobs, P.A., "A Model for Analyzing Blue Force Response to Region Invasion by Multi-Type Red Forces," forthcoming.

Gaver, D.P. and Jacobs, P.A., "Models for the Outcomes of Uncertain Task Service with Deadlines," forthcoming.

Glazebrook, K.D., "On a Military Scheduling Problem," forthcoming.

CONFERENCE PRESENTATION:

Gaver, D.P. and Jacobs, P.A., "Controlling Service When Service Completion is Uncertain," INFORMS National Meeting, Montreal, Canada, 26-29 April 1998.

OTHER:

Bullock, G., Delphi software implementation of models for Blue force response to region invasion by multi-type Red forces, December 1998.

THESES DIRECTED

Haugen, N., "An Analysis of a Delay in the Intelligence Cycle and Its Effect on a Suppression of Enemy Air Defense (SEAD) Operation," Master's Thesis, Naval Postgraduate School, September 1998.

Hencke, R.B., "An Agent-Based Approach to Analyzing Information and Coordination in Combat," Master's Thesis, Naval Postgraduate School, September 1998.

DoD KEY TECHNOLOGY AREAS: Human-System Interface, Modeling and Simulation

KEYWORDS: Combat Models, Bayesian Perception Updating, Decision Analysis

THE NAVAL SIMULATION SYSTEM (NSS) MODEL STUDY
Donald P. Gaver, Distinguished Professor
Patricia A. Jacobs, Professor
Department of Operations Research
Sponsor: U.S. Army Training and Doctrine Analysis Command-Monterey

OBJECTIVE: To provide independent reviews of the simulation model NSS to the NSS Government Program Office.

SUMMARY: Reviews of the Joint Forces Air Component Command (JFACC) support graphical user interface and the theater missile defense (TMD) graphical user interface were conducted. Documents describing the results of the review of the JFACC support graphical user interface and the theater missile defense graphical user interface have been delivered to the sponsor.

DoD KEY TECHNOLOGY AREA: Human-System Interface

KEYWORDS: Graphical User Interface, Strike Warfare

TRAINING AND RESEARCH SUPPORT FOR DIRECTOR, OPERATIONAL TEST AND EVALUATION
Donald P. Gaver, Distinguished Professor
Patricia A. Jacobs, Professor
Department of Operations Research
Sponsor: Commander, Operational Test and Evaluation Force

OBJECTIVE: Purpose of the research is to develop training and reference material on a web site and new methodology for operational testing use emphasizing modeling and simulation.

SUMMARY: Models to assess the operational suitability of UAVs have been formulated and studied. Materials for an operational test and evaluation web site have been developed. Spreadsheet implementations of the bootstrap for analysis of failure data were developed as well as a spreadsheet implementation of UAV model calculations.

PUBLICATIONS:

Gaver, D.P. and Jacobs, P.A., "Assessing and Controlling the Availability of Failure-Degraded Service Agents," Naval Postgraduate School Technical Report, NPS-OR-98-002, May 1998.

Gaver, D.P., Jacobs, P.A., and Dudenhoeffer, D.D., "Failure, Repair, and Replacement Analysis of a Navy Subsystem: Case Study of a Pump," *Applied Stochastic Models and Data Analysis*, 13, pp. 369-376, 1998.

Gaver, D.P. and Jacobs, P.A., "Methodology for an Operationally-Based Test Length Decision." *IIE Transactions* Vol. 30, 1998, to appear.

CONFERENCE PRESENTATIONS:

Gaver, D.P. and Jacobs, P.A., "Reliability Issues in Testing and Operations," Lucent Technologies, Holmdel, NJ, 9 July 1998.

Gaver, D.P., Jacobs, P.A., and Stoneman, J.G., "Modeling of UAV Sustainability for Regional Surveillance," NPS-NRL Meeting on UAVs, 26 October 1998.

THESES DIRECTED:

Stoneman, J.S., "Operational Analysis of the Sustainability of a Mobile Military Platform," Master's Thesis, Naval Postgraduate School, September 1998.

Werenskjold, George K. "An Exploratory Analysis of Corrective Maintenance During Extended Surface Ship Deployment," Master's Thesis, Naval Postgraduate School, September 1998.

DoD KEY TECHNOLOGY AREAS: Human-System Interface, Modeling and Simulation

KEYWORDS: Military Test and Evaluation, Statistical Data Analysis, Decision Analysis, Modeling and Simulation

PROJECT SUMMARIES

FORECASTING THE RETENTION OF NAVAL AVIATORS

William K. Krebs, Assistant Professor
Samuel E. Buttrey, Assistant Professor
Department of Operations Research
Sponsor: Naval Air Systems Command

OBJECTIVE: Navy, Marine, and Air Force senior leadership has stated that at the current rate of pilot resignation and that given the paucity of aviators accepting the bonus, operational readiness can be expected to decrease. The objective of this study was twofold. First, a questionnaire was developed to examine the quality-of-life issues that were important to the retention decisions of aviators. Second a statistical model was developed that predicts retention based on attributes of the aviators recorded in the Officer Master File.

SUMMARY: Approximately 1700 Navy and Marine Corps aviators were surveyed to measure their attitudes on retention. Previous research has indicated that measurements of job satisfaction are the most reliable predictor of one's intent to remain with an existing employer. The results showed that most aviators today are positively motivated by high-level needs such as affiliation (Co-worker Satisfaction) and job fulfillment (Work Satisfaction). Pay Satisfaction factors were considerably more significant for senior, than for junior, aviators as predictors of intent to remain in the service. Retirement pay concerns lent much greater impact to predicted behavior than special pay (ACP/ACIP) considerations did.

Current models of aviator retention incorporate external economic factors like civil aviation hiring. They do not take into account demographic and professional attributes of the aviators themselves, like family status, months of operational flying, and commissioning source. A statistical model was developed that used the Officer Master File (OMF) fiscal year 1995 demographic and professional aviator attributes to predict the retention behavior of the OMF fiscal year 1996 aviators. The statistical model, a classification tree, divided the aviators into a series of nodes based on a binomial distribution. At the top of the tree diagram, the first node specified that 8.7% of the 4400 aviators left military service after fiscal year 1995. The aviators who stayed in military service were then split into two separate nodes with each path categorized by commissioning source. The results showed that ROTC and Academy graduates were less likely to leave military service than those with OCS and other types of commissions. The model then further split each commission node into two more nodes that were based on a different attribute. The model continued to subdivide each node until the data better explained but not over-fit. The fiscal year 1995 and 1996 node classifications were then compared to determine whether the model could accurately predict what classes of aviators were most likely to leave military service. The predictions were fairly accurate; however the model has some shortcomings. In particular some divisions were said to be difficult to interpret. (For example, at one "branch" the tree might separate O-4s from O-3s and O-5s, although intuition would suggest that these two latter groups ought not to be similar.)

While the divisions are "correct" by the algorithm's success criterion, interpretability of the model is also a vital goal. The new model will validate the tree approach with new data as well as ensuring that all of the divisions are interpretable and "user-friendly." N1 will be able to require or prohibit specific divisions to increase the model's interpretability.

THESES DIRECTED:

Poindexter, S., "Analysis of Mid-Grade Naval Aviator Retention," Master's Thesis, Naval Postgraduate School, September 1998.

Sullivan, D., "Job Satisfaction Among United States Navy and Marine Corps' Aviation Officers - A Study of the Impact on Career Retention," Master's Thesis, Naval Postgraduate School, September 1998.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Aviators, Retention, Force Forecasting

PERCEPTUAL PLASTICITY IN A VIRTUAL ENVIRONMENT

William K. Krebs, Assistant Professor
Department of Operations Research
Sponsor: Naval Postgraduate School

OBJECTIVE: To investigate low-level perceptual-adaptation (simulator sickness) effects caused by long-term exposure to a virtual environment (VE). The cause of simulator sickness is unknown, but researchers hypothesize that it's the result of a sensory input mismatch between the visual and vestibular sensory organs. Previous simulator sickness studies used questionnaires to measure sickness severity, however this is a crude measure with inconsistent findings. To further understand the causes of simulator sickness, this study will quantify whether low-level sensory functions are disrupted when erroneous information is presented to the brain, and determine whether long-term simulator exposure causes sensory adaptation. The results of this study may identify simulator sickness symptoms, which should help mission planners optimize the length that aircrew are exposed to a virtual training.

SUMMARY: It was hypothesized that a virtual environment simulator will cause an operator's visual system to adapt and then reorganize to match the modified synthetic environment. Forty subjects were randomly assigned to one of four display formats, no exposure (control condition), CRT (29 deg FOV), three-panel display (132 deg FOV), and a HMD (Virtual Research VR8 helmet with a 60 deg FOV). The three-panel and HMD groups were immersed within a driving simulation model, while the CRT group played a video game. A battery of tests (motion sickness questionnaire MSQ, depth perception, smooth pursuit (5,10,20,30, and 36 deg/sec), and Optokinetic Nystagmus (5, 12, 18, and 25 deg/sec sinusoidal grating on the VR8 display)) were administered before and after a 25 minute treatment exposure. Subjects within the HMD showed the highest MSQ scores followed by the three-panel, CRT, and control subjects. Depth perception showed no significant difference between display formats. There was a significant difference between the three-panel and HMD groups compared to the CRT and control groups for the smooth pursuit task for subjects whom reported a history of motion sickness. This suggests that immersion may have reorganized the visual system to adapt to the virtual interface. The results of this study may provide a metric to predict initial onset of post-exposure performance degradation as well as establish standards that specify how many hours an observer may be susceptible to VE adaptation effects.

In addition to the investigation of low-level perceptual effects due to prolonged VE exposure is the study of higher order cognitive functions that interpret a VE scene. Studies on distance perception in the real world found that subjects use texture, size, and shading to estimate an object's distance. Witmer and Kline (1998) reported that subjects' distance perception within a virtual environment was not influenced by texture. This result is surprising due to the number of studies showing that texture has a significant role in distance estimation. The current study will measure the influence of texture on distance perception in a VE using a perceptual-matching task. To test this hypothesis, subjects will estimate the distance of a target displayed through a head-mounted display. Three targets of varying size will be viewed at four distances within a virtual hallway. The hallway texture will consist of three different density patterns&none, medium, and high. Subjects' task will be to estimate the distance of a briefly displayed target viewed in one hallway, turn their head 90° to view a different hallway, then physically match the distance of the previously seen target by moving a similar target along the current hallway. It is hypothesized that texture will influence distance estimation in a virtual environment, which will support previously published literature and discount Witmer and Kline's findings.

DoD KEY TECHNOLOGY AREAS: Human Systems Interface, Biomedical, Modeling and Simulation

KEYWORDS: Virtual Environment, Simulator Sickness, Adaptation

PROJECT SUMMARIES

BEYOND THIRD GENERATION: ASSESSMENT OF SENSOR FUSION FOR N88'S F/A-18 TARGETING REQUIREMENTS

William K. Krebs, Assistant Professor
Department of Operations Research
Sponsors: Office of Naval Research, Defense Advanced Research Projects Agency, and Lockheed Martin Electronics and Missiles Corporation

OBJECTIVE: The Navy and Marine Corps F/A-18 pilots state that the targeting FLIR system does not provide enough target definition and clarity. As a result, high altitude tactics missions are the most difficult due to the limited amount of time available to identify the target. If the targeting FLIR system had a better stand-off range and an improved target contrast then the pilots' task would be easier. Unfortunately, the replacement cost of the existing FLIR equipment is prohibitive. The purpose of this study is to modify the existing F/A-18 targeting FLIR system with a dual-band color sensor to improve target contrast and stand-off ranges.

SUMMARY: The Naval Postgraduate School and Naval Research Laboratory have collected simultaneous day and night-time imagery and simulated dual-band sensor fusion systems from a variety of electro-optic sensors. The basic concept of image sensor color fusion is that displaying a color fused image tends to make targets pop-out of the background as compared to a single band monochrome display. A color image emphasizes the background context and allows the user to efficiently search for a target. This in turn should improve operators' situational awareness and target recognition. For example, if color helps the operator discriminate between man-made and natural objects, then the operator will be able to identify the target quicker compared to single band monochrome systems. Flight, ground, and driving single- and dual-band data were collected to demonstrate the potential benefits of image sensor color fusion.

Flight Demonstration

A multi-color night vision system on NASA's F/A-18 Day/Night Infrared Imaging/Tracking Laser Target Designating/ Ranging System (NITE Hawk) targeting FLIR pod was demonstrated. The aircraft pod was configured with a 1st generation scanning FLIR and a color CCD. Three flights recorded video sequences of air-to-ground targets (e.g., tanks, boats) over the restricted area near Naval Air Warfare Center (NAWC) China Lake. Each sequence began with a target beyond visual range, and continued with the target within the sensor's FOV until target overfly (that is, until the target was at a range of 0 nautical miles). Subjects' task was to view the video sequences (infrared, visible, and fused color) and detect a specified target, and to announce "pickle" when the designated target had been acquired. We found that color fusion did not improve pilot's situational awareness. Pilots overwhelmingly reported that the color fused scene appeared unnatural due to the choice of colors and the problems of scene registration. The fused sequences were not able to spatially match every frame thus objects appeared distorted. However, pilots did report that color fused objects were easier to discriminate than infrared or visible objects. Therefore, color fusion may be more appropriate for targeting applications compared to navigation and pilotage applications.

Field Data Collection

Ground-based data collection was conducted on April 14th and 15th, 1998 at Fort A.P. Hill, Virginia to gather data for sensor fusion development. This data collection was the second in a series, which started in the fall of 1997 and will continue through 1998. The Fort A.P. Hill data collection used four different spectral sensors boresighted within a vertical integrated sensor mount. The test consisted of a Lockheed Martin IR & Imaging Systems (LMIRIS) uncooled long-wave infrared sensor, Amber Radiance mid-wave infrared camera, Lockheed Martin (LM) Fairchild low-light camera, and a Pulnix TM-540 visible near infrared camera. The test methodology consisted of five different scenarios that varied across terrain (open field to dense forest) by target types (M2 Bradely, M60, M113 APC, M35 2.5 ton truck, and a HMMWV). Each data collection session lasted approximately eight hours with four scenarios tested each session. The majority of data was collected during full moon illumination with a couple of hours during sunrise. Meteorological and GPS data on selected targets were collected during both sessions. Within each session, analog video was continually recorded for each sensor and selected digital segments were recorded using a specially configured portable digital collection workstation. Digital sequences were limited to three minutes, thereby allowing time to archive the digital files.

Digital and analog data was used to evaluate the information conveyed by single- and dual-band sensor imagery by assessing operator performance on a scene recognition task. Subjects viewed a 100-msec image followed by a 300-msec checkerboard mask. A second image, of the same or of a different sensor format, was then displayed and remained visible until a response was made. The observer's task was to indicate whether the first and second image depicted the same scene, regardless of which sensor format the scenes were displayed in. Performance was best when the first and second images were presented in the same format. When format changed between the presentation of the two images, performance deteriorated, but more so when the second image was of a single band format. Format of the first image itself had little effect, indicating that the primary benefits of sensor fusion were in matching the content of the second image to a stored representation of the first, and not in processing the briefly viewed first image. These results suggest that fusion can allow information from multiple single-band sensors to be effectively combined and presented within a single image, within which single-band information remains perceptually accessible.

Driving Demonstration

Infrared and image-intensified videotaped footage was collected from sensors mounted to the roof a moving sport utility vehicle, and psychophysical tests have begun to examine how these different sensor types support various perceptual abilities integral to safe night driving—the ability to detect obstructions, the ability to see through the glare of oncoming headlights, the ability to estimate the time until an approaching vehicle passes. An initial study has examined observers' ability to detect a pedestrian against the glare of an approaching car's headlights. Images for this experiment were collected with the sensors facing down a stretch of straight road, and into the headlights of a parked car. Later, in the lab, observers were asked to view these images and to determine whether a pedestrian was visible in each one. Response times for detecting pedestrians were faster in infrared than in image-intensified imagery. More notably, observers' performance using image-intensified imagery declined substantially as targets were located at greater distances from the sensor, and as targets were located nearer the oncoming vehicle's headlights, while performance with infrared imagery showed little effect of target distance or of interference from glare. This suggests that infrared sensors might be effective night driving aids, and could be especially helpful in overcoming difficulties imposed by glare.

Task Analysis and Predictive Model

A task analysis was conducted to determine what measures are needed to assess the benefits of sensor fusion for military applications. This task analysis consisted of an extensive framework for evaluating sensors, algorithms and operator performance across different but relevant combinations of spectral wavebands. The results of the task analysis were then used to develop quantifiable performance-based metrics to be used in evaluating fused imagery systems requirements and performance.

The second objective was to modify existing analytical operations-research-type models to fit meaningful performance metrics that could be revised and extended where necessary to represent the data obtained during field tests. These modified models may be used to evaluate fused imagery systems requirements and performance. Furthermore, these models may indicate what type of data would be needed to collect in the future.

THESES DIRECTED:

Bryant, E., "A Process Simulation Design to Assess Promising Technologies Relevant to F/A-18 Aircrew Target Recognition," Master's Thesis, Naval Postgraduate School, September 1998.

White, B., "Evaluation of the Impact of Multispectral Image Fusion on Human Performance in Global Scene Processing," Master's Thesis, Naval Postgraduate School, March 1998.

DoD KEY TECHNOLOGY AREAS: Human Systems Interface, Modeling and Simulation, Air Vehicles, Sensors, Ground Vehicles

KEYWORDS: Sensor Fusion, Multi-Spectral, Human Performance, Target Recognition, Driving Aids, Enhanced Vision

MODELING ATTRITION OF FIRST-TERM ARMY ENLISTED PERSONNEL

Harold J. Larson, Professor
Samuel E. Buttrey, Assistant Professor
Department of Operations Research
Sponsor: Office of the Deputy Chief of Staff, Personnel (ODCSPER), U.S. Army

OBJECTIVE: The Army is updating its military strength management system. That system is used for modeling near-term needs for, and adjustments to, manpower levels, as well as for longer term projections. One portion, the Enlisted Loss Inventory Model (ELIM), projects losses of first-term enlisted personnel. The model bases its projections on characteristic groups (c-groups), whose structure has remained unchanged since the strength management system was initially implemented. These c-groups partition first-term enlisted personnel according to sex, education level, mental category (AFQT group) and term of service in a specific way. It is presumed that members of different c-groups will have different propensities toward attrition. In recent years, however, forecasts made by the ELIM model have not been satisfactory.

This study used Classification and Regression Tree methodology (CART) to generate c-groups for use with ODCSPER's new Military Strength Management System; these new c-groups are designed to differ in first-term retention rates, to the maximum extent possible. As this project continued, interest was also expressed in categorizing differences in retention in the early months of a recruit's first term. In addition, interest arose in groupings which distinguished three groups: those who did not complete the first term, those who did complete the first term but did not re-enlist, and those who did choose to re-enlist at the completion of the first term. CART has also been used for these efforts.

SUMMARY: This project was completed at the end of calendar year 1998, and the final report has been delivered to the sponsor. The CART methodology has been useful in defining new c-groups in which attrition rates varied somewhat more that the old. Misclassification rates are also reduced; the improvement is small in percentage terms but reasonably large in terms of the increased number of correct predictions. The technique also demonstrated that attrition rates peak in the early months and reach a steady-state by about month nine; that race and sex are important factors in producing groups with different attrition rates, and that both the peak and steady-state rates are highest for white females and lowest for non-white males. This is partly, but not entirely, because females, especially white females, tend to sign up for the longest terms. The best groups for predicting re-enlistment differ somewhat from those that are best for predicting completion. Finally, the college bonus programs do play a role in re-enlistment, as suspected, but not in term completion.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: CART, Retention, Force Forecasting

ADDRESSING UNCERTAINTIES AND RANDOMNESS IN DECISION MAKING

Tom Lucas, Associate Professor
Department of Operations Research
Sponsor: Naval Postgraduate School

OBJECTIVE: To develop methods that assist decision makers make and justify decisions in an uncertain environment with a dearth of data. This will be addressed in two ways. First, by facilitating the use of Bayesian methods by identifying robust approaches to explicitly combine expert's subjective assessments with (scarce) data. Second, develop approaches to better address uncertainty in (combat) simulations.

SUMMARY: Towards the goal of enhancing the ability to quantify prior beliefs, through extensive numerical computations: (1) a (first-cut) list of asymptotic behaviors were developed for a variety of prior functional forms when the data conflicts with how prior beliefs are modeled and (2) how some oft-used models behave were determined with respect to extreme data. It turns out that some of the more popular models make non-robust (implicit) assumptions that seem unreasonable.

To help advance the debate on whether combat simulations should (generally) be deterministic or stochastic: (1) a list of arguments were assembled (both theoretical and practical) for and against deterministic approximations to inherently

PROJECT SUMMARIES

stochastic phenomenon in combat models and (2) a diverse set of examples were gathered where the deterministic approximations severely bias simulation outputs.

PUBLICATIONS:

Lucas, T., Bennett, B., Friel, J., and Kerchner, R., "ADS for Analysis: Much Agreement, Important Differences," *PHALANX*, December 1998.

Lucas, T., "Why Most Combat Models Should be Stochastic: Tales of When the Average Won't Do," in final preparation.

Lucas, T., "The Warfighting Experiment Analytical Process—Where Do We Go From Here?" in final preparation.

CONFERENCE PRESENTATIONS:

Lucas, T., "The Warfighting Experiment Analytical Process—Where Do We Go From Here?" U.S. Army Conference on Applied Statistics (ACAS), Las Cruces, NM, October 1998.

Lucas, T., "Improving the Analytical Contribution of Advanced Warfighting Experiments," 2nd Center for Military Analysis/Naval Postgraduate School Meeting, Haifa, Israel, July 1998.

OPTIMIZING INTERMODAL RAIL OPERATIONS
Alexandra M. Newman, Research Assistant Professor
Department of Operations Research
Candace A. Yano, Professor and Chair
Industrial Engineering and Operations Research Department
University of California, Berkeley
Sponsor: Unfunded

OBJECTIVE: To develop new techniques for solving large integer programming models with an application in the rail industry for minimizing operational costs of intermodal train scheduling and container routing.

SUMMARY: The problem was addressed of how to schedule direct and indirect (via a hub) trains and which containers to send on each train for the rail (linehaul) portion of the intermodal trip. The goal is to minimize operational costs, including a fixed charge for each train, variable transportation and handling costs for each container and yard storage costs, while meeting on-time delivery requirements. The problem was formulated as an integer program and develop a novel decomposition procedure to find near-optimal solutions. A method was also developed to provide relatively tight bounds on our solution values. Finally, the solutions were compared against those obtained with heuristics designed to mimic current operations, and show that a substantial savings can be gained from using the solution procedure.

PUBLICATION:

Newman, Alexandra M. and Yano, Candace A., "Optimizing Intermodal Rail Operations," *Proceedings of the 1998 Manufacturing and Service Operations Management Conference,* Seattle, WA, 29-30 June 1998.

CONFERENCE PRESENTATIONS:

Newman, Alexandra M. and Yano, Candace A., "Optimizing Intermodal Operations over the Rail (Linehaul) Segment of Truck-Rail Intermodal Transportation," Institute for Operations Research and the Management Sciences Conference, Montreal, Quebec, 26-29 April 1998.

44438

Newman, Alexandra M. and Yano, Candace A., "Optimizing Intermodal Rail Operations," Manufacturing and Service Operations Management Conference, Seattle, WA, 29-30 June 1998.

Newman, Alexandra M. and Yano, Candace A. "Optimizing Intermodal Rail Operations," Institute for Operations Research and the Management Sciences Conference, Seattle, WA, 25-28 October 1998.

OPERATIONS RESEARCH MODELING FOR OSD (PA&E)
Richard E. Rosenthal, Professor
Arnold H. Buss, Visiting Assistant Professor
Department of Operations Research
Sponsor: Office of Secretary of Defense, Program Analysis and Evaluation

OBJECTIVE: To enable Operations Research masters students at the Naval Postgraduate School to take field trips in connection with thesis research on topics of interest to OSD (PA&E), such as understanding of focused logistics.

SUMMARY: This project supported LCDR John Ruck's thesis research on focused logistics, conducted at the request of Mr. James Johnson of OSD (PA&E). The principal accomplishment was the development of the Flexible Experimental Logistics Simulator (FLEXLOGS), whose purpose is the inclusion of logistics-based constraints and considerations in combat models. FLEXLOGS is an object-oriented, discrete-event simulation that can be used to evaluate proposed logistics strategies. The model was used to explore the probability of combat victory vs. "logistical footprint size" and "premium transportation availability."

THESIS DIRECTED:

Ruck, John L., "An Object-Oriented Discrete-Event Simulation of Logistics (Modeling Focused Logistics)," Master's Thesis, Naval Postgraduate School, September 1998.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Focused Logistics, Object-Oriented Modeling and Simulation

ADVANCED TOMAHAWK WEAPONS CONTROL SYSTEM PREDESIGNATION
Alexandra M. Newman, Research Assistant Professor
Richard E. Rosenthal, Professor
Department of Operations Research
Sponsors: Naval Surface Warfare Center-Dahlgren Division
and Office of Naval Research

OBJECTIVE: To improve modeling efforts to aid in the selection and firing of Tomahawk missiles from surface ships and submarines (ongoing).

SUMMARY: Tomahawk Land Attack Missile allocation for tasking requirements has traditionally been done manually. Automatic selection of these missiles would improve accuracy and consistency in selection, preserve residual firing capabilities, decrease unnecessary missile expenditure and save valuable time for the strike control officer. This project developed a new optimizing approach to missile-to-mission matching, using integer programming. In a matter of seconds for a single ship or a matter of minutes for a battle group, the optimization model determines which missile to select for each tasking order and provides back-up assignments if requested. The objective of this first model is to ensure the best weapon is applied against each target while maximizing the salvo capability of the firing units to perform future taskings. This accounting of future taskings is indirect; therefore, ongoing research aims to develop a dynamic version of the model that considers tasking orders over multiple time periods. Other enhancements in the second model will be to take into account

the initial geographic location of ships, preferences as to how missile firings are allocated to ships, and the relative importance of various taskings. A separate, but related, model will be developed for TLAM allocation on submarines.

THESIS DIRECTED:

Kuykendall, S.D., "Optimizing Selection of Tomahawk Cruise Missiles," Master's Thesis, Naval Postgraduate School, March 1998.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Surface/Under Surface Vehicles – Ships and Watercraft

KEYWORDS: Missiles, Missile Selection, Naval Operations, Tomahawk Land Attack Missile

PLANNING PROCUREMENT AND DEPLOYMENT OF SPACE AND MISSILE ASSETS
Alexandra M. Newman, Research Assistant Professor
Gerald G. Brown, Professor
Robert F. Dell, Associate Professor
Richard E. Rosenthal, Professor
Department of Operations Research
Sponsor: U. S. Air Force Space Command

OBJECTIVE: To improve modeling efforts to aid in the procurement of space-based systems over a 25-year time horizon (ongoing).

SUMMARY: The Space Command Optimizer of Utility Toolkit (SCOUT) is a linear integer model developed for the Air Force Space Command to help plan the research and development of space-based systems over a 25-year horizon. SCOUT recommends a mix of concepts, current systems, and launches that minimizes shortfalls in task performance, while adhering to constraints on budget, launcher demand, launcher availability, and logic governing the precedence and interdependence of systems. The current research goal is to improve SCOUT's value to the Air Force Space Command by enhancing model realism and by decreasing the computer time necessary to complete a model run.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Space Vehicles

KEYWORDS: Budgeting, Capital Budgeting, Space Systems

CONFIGURATION MODELING FOR THE RELIABILITY OF SHORT TAKE-OFF AND LANDING AIRCRAFT
Robert R. Read, Professor
Department of Operations Research
Sponsor: Naval Postgraduate School

OBJECTIVE: To contribute to the understanding of the effect of the proposed configurations on the reliability and maintainability of several notional Joint Strike Fighter aircraft, one of conventional take-off and landing type, and two of the short take-off and vertical landing type.

SUMMARY: Reliability and maintainability studies were made of three designs proposed for the Joint Strike Fighter (JSF): (1) the conventional take-off and landing carrier based aircraft (CV/CTOL); (2) the short take-off and vertical landing (STOVL) of the direct lift type; and (3) STOVL of the lift fan type. The studies took two main forms: (1) a literature search into the characteristics and complexities of the several types and (2) a modeling of the structural components affected by the advanced designs in terms of the failure histories of existing components that play similar roles in operational

aircraft. Such modeling allows the program managers to anticipate the extent of engineering improvements necessary in order to make the proposed aircraft designs viable and competitive. Several complexity comparisons were made. Reliability computations were made both for the attrition phase and the mission capability aspects for all three designs. Comparisons were made with like computations for the Harrier and Hornet aircraft.

PUBLICATION:

Read, R.R., "Summary of the Reliability and Maintainability Research Relating to the Joint Strike Fighter Program," Naval Postgraduate School Technical Report, NPS-OR-98-007, October 1998.

THESIS DIRECTED:

Boyles, D.E., "A Reliability and Availability Analysis of Notional Joint Strike Fighter Aircraft Designs," Master's Thesis, Naval Postgraduate School, September 1998.

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Reliability, Maintainability, Joint Strike Figher, CV/CTOL, STOVL

ESTIMATING THE MEAN WHEN SAMPLING PROVIDES PROBABILITIES AS WELL AS VALUES
Robert R. Read, Professor
Alan Washburn, Professor
Department of Operations Research
Lyn Thomas, Professor
University of Edinburgh
Sponsor: Unfunded

OBJECTIVE: To develop schemes for leveraging the extra information provided when the value probabilities are included as output along with the measured values. The goal of sampling is to estimate a population mean. It should be possible to improve upon the arithmetic average of the values under these circumstances.

SUMMARY: This is a continuing project. Previous work has produced some criteria for judging good estimates and four techniques for using the extra information to advantage. Some performance comparisons have been generated using Monte Carlo simulation. The work of the current year has resulted in the detailing of some new problems to which our structure applies, and the enhancement of one of out estimators by the development of a confidence interval technique for it.

DoD KEY TECHNOLOGY AREA: Other (Mathematical Models)

KEYWORDS: Probability, Monte Carlo Simulation

COSTS IN THE FUTURE OF NAVAL AVIATION
Robert R. Read, Professor
Department of Operations Research
Sponsor: Naval Postgraduate School

OBJECTIVE: To create a spreadsheet cost model that allows "what if" studies to be conducted for a variety of notional configurations of Naval aviation for the period 2000 to 2020.

SUMMARY: This work is in support of a much larger project, "Innovation in Naval Warfare Systems," under the direction of Professor Mike Melich of NPS' Institute for Joint Warfare Analysis in which operational capability and combat system procurement issues play central roles. The notional plans for Naval aviation for the period 2000 to 2020 have been acquired including the aircraft carrier build and retirement programs, mix of aircraft types, weapons and personnel requirements. Cost categories have been identified.

PUBLICATIONS:

Read, R.R., "Errors of the First and Second Kinds," *Encyclopedia of Industrial Engineering,* A. Mital, (ed.), 1998.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORD: Naval Aviation

OPTIMIZATION MODELING FOR AIRLIFT MOBILITY
Richard E. Rosenthal, Professor
Laura M. Williams, Research Assistant Professor
Department of Operations Research
Sponsor: U.S. Air Force Studies and Analysis Agency

OBJECTIVE: To provide research and support for the Air Force air mobility modeling effort by enhancing the Naval Postgraduate School/RAND Mobility Optimizer (NRMO) model and supporting studies performed with the model.

SUMMARY: Tutorials on the NRMO model were given to both AFSAA and RAND personnel. Support for the OSD(PA&E) Fuels Infrastructure Study being done at RAND was given. This support included creating scenarios, making model runs, performing analysis of model results, and making model enhancements. Enhancements made to the model included: data support for the aerial refueling function, cargo load factors, home station servicing, and fractional flows.

PUBLICATION:

Baker, S.F. and Rosenthal, R.E., "A Cascade Approach for Staircase Linear Programs," Naval Postgraduate School Technical Report, NPS-OR-98-004, July 1998.

CONFERENCE PRESENTATION:

Baker, S.F., "NRMO Status Update," Air Force Air Mobility Modeling and Simulation User's Conference, Air Force Academy, Colorado Springs, CO, May 1998.

THESIS DIRECTED:

Damm, E., "A Comparison of the Force Deployment Estimator (FDE) and Navel Postgraduate School/RAND Mobility Optimizer (NRMO) as Tools for Mobility Analysis," Master's Thesis, Naval Postgraduate School, September 1998.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Mobility, Air Mobility, Optimization

GENERALIZED NETWORK ENLISTED COMPONENT
OF THE ACTIVE ARMY STRENGTH FORECASTER (A2SF)
Richard E. Rosenthal, Professor
Laura M. Williams, Research Assistant Professor
Department of Operations Research
Sponsor: Office of the Deputy Chief of Staff, Personnel (ODCSPER), U.S. Army

OBJECTIVE: To research, design, and implement a prototype generalized network model for the enlisted component of the Active Army Strength Forecaster (A2SF). The purpose of the model is to maintain the Army's enlisted force as closely as possible to prescribed levels.

SUMMARY: Two models have been designed and implemented: (1) a model with both the grade and specialty detail and (2) a model with the grade detail, but aggregated with respect to specialty, called the Enlisted-Grade (EG) model. The EG model was found to be easier to solve than the original grade and specialty detail model, and was also found to be sufficient to meet the needs of the client. Preliminary verification efforts have begun in preparation for delivery and integration with the A2SF system.

CONFERENCE PRESENTATION:

Williams, L., "Generalized Network Enlisted Forecasting Model," British-American Army Forecasting Exchange Conference, West Point, NY, May 1998.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Manpower, Optimization

METHODOLOGY RESEARCH IN WARGAMING/ANALYSIS
Richard E. Rosenthal, Professor
Laura M. Williams, Research Assistant Professor
Lt Col Kirk A. Yost, USAF, Ph.D. Student
Department of Operations Research
Sponsor: Joint Chiefs of Staff (J-8)

OBJECTIVE: To provide models and analysis which enhance the Capabilities-Based Munitions Requirement (CMBR) process developed by the Under Secretary of Defense for Acquisition and Technology as well as the analysis of force projection and force structure options.

SUMMARY: Studies were conducted in two areas: (1) A multi-objective optimization model was developed that attempts to find an optimal allocation of munitions to threats with limited overlap among the services. The allocation was based on three objectives: minimize friendly casualties, maximize enemy casualties and maximize adherence to the guidance delineating proper division of labor among the services. (2) The Naval Postgraduate School/RAND Mobility Optimizer (NRMO) model was upgraded by adding a sealift component. A comparative analysis of the resulting model (NRMOAS) and the model currently used for force deployment modeling (FDE) was performed.

CONFERENCE PRESENTATION:

Byrne, P.C., Rosenthal, R.E., and Widdowson, B.L., " A Joint Service Optimization of the Phased Threat Distribution," Military Operations Research Society Symposium, Monterey, CA, June 1998.

PROJECT SUMMARIES

THESES DIRECTED:

Widdowson, B.L., "A Joint Service Optimization of the Phased Threat Distribution," Master's Thesis, Naval Postgraduate School, March 1998.

Damm, E.M., "A Comparison of the Force Deployment Estimator (FDE) and Naval Postgraduate School/RAND Mobility Optimizer (NRMO) as Tools for Mobility Analysis," Master's Thesis, Naval Postgraduate School, September 1998.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Phased Threat Distribution, Multiple Objectives, Goal Programming, Optimization, Mobility, Air Mobility, Sea Mobility, Force Deployment, Force Projection

READINESS ASSESSMENT
David A. Schrady, Distinguished Professor
Department of Operations Research
Sponsor: Deputy Undersecretary of Defense (Readiness)

OBJECTIVE: The objective was to structure measures of military readiness which allow broad discussion of the subject within the military, with the Congress, and with the public at large.

SUMMARY: Though readiness is a commonly used concept, it lacks formal specification and is understood to mean different things to different persons. This state of affairs complicates discussion of readiness and decisions about the level of readiness which should be funded and maintained. The U.S. economy was seen as something which similarly is of broad interest but not formally specified. It was noted that the government established a number of indicators or indices in order to aid discussion and policy making with respect to the economy and that individuals, corporations, and government policy makers find the baseline and trend information in these indicators and indices useful. Readiness indicators were proposed, motivated by the analogy with economic indicators and indices.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Military Readiness, Joint Readiness, Readiness Assessment

TACTICAL LOGISTICS SUPPORT SYSTEM AND SEA-BASED LOGISTICS
David A. Schrady, Distinguished Professor
Department of Operations Research
Sponsor: Naval Sea Systems Command

OBJECTIVES: The first objective was to change the Tactical Logistics Support System (TACLOGS) software so that it complies with DII COE standards. The second objective was to begin modeling sea-based logistics support for its eventual inclusion in TACLOGS.

SUMMARY: Several minor changes were made in the existing version of TACLOGS, changes suggested by at-sea use of TACLOGS. Additionally the classified database for TACLOGS was updated to reflect changes in standard air wing composition and changes in standard ordnance load lists. The biggest task has been to rewrite the software in JAVA, to create the HCIs with Visual Café, and to incorporate compliance with DII COE 3.1. The new version of TACLOGS will be compatible with the Global Command and Control System-Maritime 3.1 that will become the Navy standard during 1999 and will run on any platform including a PC with Windows NT 4.0 operating system. The rewrite is not finished, but it is

expected to be finished in time to be included in the SQT2 operational evaluation of GCCS-M 3.1 in the Spring. Work on sea-based logistics modeling has been secondary to the TACLOGS efforts.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Naval Logistics, Sustainability

SEA-BASED LOGISTICS
David A. Schrady, Distinguished Professor
Department of Operations Research
Sponsor: Naval Postgraduate School-Institute for Joint Warfare Analysis

OBJECTIVE: Quantitative analysis of the operational aspects of the concept of sea-based logistics (SBL) including characterization of the range of types and sizes of forces to be supported by SBL, estimation of the sustainment requirements of such forces, and determination of the feasibility of SBL sustainment for the forces postulated.

SUMMARY: Five representative missions were developed for a Marine Expeditionary Unit embarked in an amphibious readiness group of three amphibious warfare ships that would be called upon to provide their sea-based logistics support. For each mission, sustainment requirements were developed from planning factors in the MAGTF Data Library. Under the assumption that force deployment would involve surface and vertical lift and that resupply would be by vertical lift only, the number of aircraft sorties required daily to sustain the force involved in each mission was calculated. Required combat support sorties were compared to the total number of sorties available. An observation drawn is that SBL may require most of the sorties of aircraft which up to now have been considered to have exclusively tactical roles.

THESIS DIRECTED:

Hagan, Robert M., "Modeling Sea-Based Sustainment of Marine Expeditionary Unit (Special Operations Capable) (MEU(SOC) Operations Ashore," Master's Thesis, Naval Postgraduate School, September 1998.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Sea-Based Logistics, Sustainability, OMFTS, STOM

TARGET SELECTION IN FORCE-ON-FORCE ATTRITION ALGORITHMS
James G. Taylor, Professor
Department of Operations Research
Sponsor: U.S. Army Concepts Analysis Agency

OBJECTIVE: To investigate models for target selection for the attrition-calibration (ATCAL) approach for assessing aggregated force-on-force attrition of large ground-combat units in campaigns for the purposes of joint-warfare, campaign analysis.

SUMMARY: Documentation of last year's work was completed. Last year, a general framework for viewing aggregated-force attrition models/algorithms was developed and used as a point of departure for developing methodology for the theoretical comparison/evaluation of existing attrition methodologies. Three major methodologies for aggregated ground-combat attrition were identified and a comparative evaluation of them made. The theoretical basis of the ATCAL method was investigated (e.g., the underlying Lanchester-type equations were developed). Computational methods for determining losses of large-scale ground-combat forces were investigated, as well as the context (including supporting calculations and determinations) for such assessments.

CONFERENCE PRESENTATION:

Taylor, J.G., Mansager, B.K., and Brown, R., "Redesign of ATCAL Attrition Algorithm for Military OR Problems in the Twenty-First Century," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Combat Models, Lanchester Attrition-Rate Coefficient, Target Selection

RESEARCH ON AGGREGATED COMBAT MODELS II
James G. Taylor, Professor
Department of Operations Research
Sponsor: U.S. Army Concepts Analysis Agency

OBJECTIVE: To improve quantitative methodology for assisting in the selection of aggregated-force combat models and submodels, particularly for the attrition process. Also, to improve attrition methodologies for such models.

SUMMARY: This work was the continuation of last year's research on target selection for the attrition-calibration (ATCAL) methodology used extensively by CAA in their large-scale combat models. Research focused on determining the theoretical basis of ATCAL (i.e. underlying conceptual and mathematical models and solution methodology for the mathematical equations) and identifying how to improve it. Based on development of general hierarchy-of-models methodology, the ATCAL algorithms (both replay model and estimation of parameter values from high-resolution-combat-simulation output) were completely re-engineered and suggestions for short-term improvement (of the existing algorithms) developed. Also, a critique of the proposed JWARS ground-combat attrition methodology was written. The director of CAA will be briefed on these accomplishments in early 1999. The critique of the proposed JWARS ground-combat attrition methodology was briefed to senior OSD PA&E managers and the Scientific Advisor of The Joint Staff (October 1998) and AMSO's Standards Coordinating Committee (SCC) for Attrition (December 1998). As a result of this, the investigator was made a member of the Army Modeling and Simulation Office (AMSO) SCC for attrition. Also, improvements that overcome a fundamental flaw that had gone undetected for about 25 years were made in so-called Bonder-Farrell attrition methodology. A very serious flaw (that had gone undetected for about fifteen years) in how ATCAL determines its target-priority list for so-called Phase II calculations was discovered.

CONFERENCE PRESENTATIONS:

Taylor, J.G., "Initial Theoretical Evaluation of JWARS Ground-Combat Attrition Model," AMSO Attrition Meeting, Attrition Standards Coordinating Committee (SCC) of the Army Modeling and Simulation Office (AMSO), Aberdeen Proving Ground, MD, 15 December 1998.

Taylor, J.G., "Single-System Kill Rates by the Bonder-Farrell Approach," AMSO Attrition Meeting, Attrition Standards Coordinating Committee (SCC) of the Army Modeling and Simulation Office (AMSO), Aberdeen Proving Ground, MD, 15 December 1998.

Taylor, J.G., "Markov-Chain Models of Target Availability," AMSO Attrition Meeting, Attrition Standards Coordinating Committee (SCC) of the Army Modeling and Simulation Office (AMSO), Aberdeen Proving Ground, MD, 15 December 1998.

Taylor, J.G., "Overview of Aggregated-Force Attrition Methods," INFORMS Cincinnati Spring 1999 Meeting, Cincinnati, OH, 29 April-6 May 6, 1999, to be given.

Clark, G.M., Buss, A.H., and Taylor, J.G., "Hierarchy-of-Models Approach for Determining Lanchester Attrition-Rate Coefficients," INFORMS Cincinnati Spring 1999 Meeting, Cincinnati, OH, 29 April-6 May 1999, to be given.

THESIS DIRECTED:

Shenk, Michael L. "Development of a Test Mechanism for Analyzing Force Attrition Methodologies within Aggregated Combat Simulations," Master's Thesis, Naval Postgraduate School, June 1998.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Ground-Force-on-Force Attrition, Attrition-Calibration (ATCAL) Method, Joint Warfare System (JWARS)

SUPPORT AND REVIEW OF THE MODELING OF GROUND COMBAT IN INTEGRATED THEATER ENGAGEMENT MODEL (ITEM)
James G. Taylor, Professor
Department of Operations Research
Sponsor: Joint Training, Analysis, and Simulation Center (JTASC)

OBJECTIVE: To provide necessary background and inputs for specific topics/methodologies (concerning the representation of ground combat) of interest to the Joint Training, Simulation and Analysis Center (JTASC) to support its use/development of the Integrated Theater Engagement Model (ITEM).

SUMMARY: This work continued a project started last year. In the previous year, the theoretical basis of the attrition-calibration (ATCAL) method for assessing aggregated force-on-force attrition was investigated (e.g. the underlying Lanchester-type equations were developed for the case of point-fire attrition, the limiting behavior of these equations was investigated). An initial computational investigation revealed that substantial errors might be involved in the use of an exponential-decay assumption in the ATCAL algorithm. Consequently, major changes in the computational methods (e.g., numerical integration and maximum likelihood estimation of model parameters) for ATCAL were proposed and some details worked out. This year further details were worked out and documented.

PUBLICATION:

Taylor, J.G., Mansager, B.K., Buss, A.H., and Brown, R., "On The Theoretical Bases of the Attrition-Calibration (ATCAL) Method, with Applications to Algorithm Development," *Proceedings of the First National Meeting of the Military Applications Society*, Huntsville, AL, May 1998.

Taylor, J.G., "Mathematical Analysis of the Underlying Lanchester-Type Models for COMAN/ATCAL," *Proceedings of the First National Meeting of the Military Applications Society*, Huntsville, AL, May 1998.

CONFERENCE PRESENTATIONS:

Taylor, J.G., Mansager, B.K., Buss, A.H., and Brown, R., "On The Theoretical Bases of the Attrition-Calibration (ATCAL) Method, With Applications to Algorithm Development," First National Meeting of the Military Applications Society, Huntsville, AL, 19-21 May 1998.

Taylor, J.G., "Mathematical Analysis of the Underlying Lanchester-Type Models for COMAN/ATCAL," First National Meeting of the Military Applications Society, Huntsville, AL, 19-21 May 1998.

Taylor, J.G., "Suggested Changes in the Integrated Theater Engagement Model (ITEM)," ITEM User's Group Meeting, San Diego, CA, 15 July 1998.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Ground-Force-on-Force Attrition, Attrition-Calibration (ATCAL) Method, Joint-Warfare Campaign Models

NEW METHODOLOGY FOR AGGREGATED COMBAT MODELS
James G. Taylor, Professor
Department of Operations Research
Sponsor: U.S. Marine Corps Combat Development Command

OBJECTIVE: To evaluate the adequacy of existing combat-modeling methodologies (especially for attrition) and models (especially JWARS) for current and future USMC Combat Development Command analysis needs.

SUMMARY: Work was barely initiated on development of a hierarchy-of-models approach to modeling combat attrition in situations of interest to the sponsor, when the investigator became concerned about the proposed JWARS ground-combat attrition methodology. A critique was made (PowerPoint presentation) and reported to the sponsor. This critique was briefed to senior OSD PA&E managers and the Scientific Advisor of The Joint Staff (October 1998) and later AMSO's Standards Coordinating Committee (SCC) for Attrition (December 1998). As a result of this, the investigator was made a member of the Army Modeling and Simulation Office (AMSO) SCC for attrition. This has also led to the investigator developing (an alternate/risk-mitigating) attrition methodology for WARSIM, the Army's part of JSIMS (and an area of interest to the USMC).

CONFERENCE PRESENTATION:

Taylor, J.G., "Overview and Directions for Aggregated-Force Combat Models," 67th Military Operations Research Society Symposium, West Point, NY, June 22-24, 1999 (to be given).

OTHER:

Project presentation given to senior pentagon officials (Jim Johnson, Director OSD PA&E Ground Forces, Eric Colter, OSD PA&E Force Projection, Dr. Kevin Saeger, Director Joint Data System OSD PA&E, and Vince Roeske, Scientific Advisor The Joint Staff): Taylor, J.G., "Initial Theoretical Evaluation of JWARS Ground-Combat Attrition Model," Project Presentation for MCCDC, Quantico, VA, October 1998.

Taylor, J.G., "Single-System Kill Rates for the Bonder-Farrell Approach," Project Presentation for MCCDC, Quantico, VA, October 1998.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Ground-Force-on-Force Attrition, Attrition-Calibration (ATCAL) Method, Joint Warfare System (JWARS)

SUPPORT OF COMBAT MODELING
James G. Taylor, Professor
Department of Operations Research
Sponsor: Simulation and Analysis Center, Office of the Secretary of Defense

OBJECTIVE: To provide necessary background and inputs for specific topics/methodologies of interest to the Simulation and Analysis Center (SAC) to support its use/development of computer-based combat models.

SUMMARY: This was the completion of a project initiated in the previous year. Last year, the theoretical basis of the attrition-calibration (ATCAL) method for assessing aggregated force-on-force attrition was investigated (e.g., the underlying Lanchester-type equations were developed for the case of point-fire attrition). The goodness of the approximation upon which the attrition algorithm is based was partially investigated. The basic ATCAL assessment equations (upon which the ATCAL attrition algorithm for the case of point-fire attrition is based) were derived from these underlying Lanchester-type equations. The limiting behavior of these equations was investigated. This year the mathematical behavior of the underlying Lanchester-type differential equations for ATCAL was investigated.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Joint-Warfare Models, Aggregated-Force Attrition, Lanchester-Type Models

NPS SUPPORT FOR UAV CONOPS DEVELOPMENT
Alan Washburn, Professor
Department of Operations Research
Sponsor: Chief of Naval Operations (N88)

OBJECTIVE: Unmanned aerial vehicles will play an important role in future naval operations, but operational concepts need to be worked out. This research examines one of the many tasks that UAVs might undertake: Surface Search and Surveillance (SSC).

SUMMARY: UAVs will undertake tasks that are dangerous, dirty, and/or dull. SSC is one of the dull kind. A battle group must keep track of all contacts within several hundred miles of PIM (the group center). Contacts are easy to detect by active means, but must still be overflown to establish identity and intent. A vertical takeoff and landing (VTOL) UAV based on a helicopter platform can make a significant contribution to accomplishing this SSC mission. The UAV's role will be to make repeated flights, each of which visits one or more targets of interest. The utility of the UAV will depend on its sensors, its speed and endurance, its command and control system, its method of prioritizing targets, and on unrelated parameters such as target density and battle group speed. The Monte Carlo simulation UAV_SSC developed in this project is designed to facilitate assessment of UAV utility.

OTHER:

UAV_SSC is a Visual Basic simulation of a UAV in the SSC role. It has both graphic and statistical modes, with the latter being the former speeded up by omitting the pictures. It simulates a battle group proceeding at a fixed speed and direction through a sea containing targets proceeding at a different fixed speed and in random directions. Targets entering the battle group's envelope eventually are visited by the UAV, perhaps repeatedly if they are "bad guys." UAV_SSC is available from the author at washburn@nps.navy.mil.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Modeling and Simulation

KEYWORDS: VTOL, UAV

FAMILIARIZATION OF NPS FACULTY WITH SUBMARINE SECURITY PROBLEMS
Alan Washburn, Professor
James Eagle, Professor
Department of Operations Research
Sponsor: Applied Physics Laboratory, Johns Hopkins University

OBJECTIVE: To allow Professors Washburn and Eagle to visit APL/JHU and familiarize themselves with the submarine security problems being pursued.

SUMMARY: Professors Washburn and Eagle visited APL/JHU several times and discussed several submarine security problems.

DoD KEY TECHNOLOGY AREA: Undersea Warfare

KEYWORDS: Submarine Security

LARGE-SCALE MIXED INTEGER PROGRAMMING
R. Kevin Wood, Associate Professor
Department of Operations Research
Sponsor: Joint Warfare Analysis Center

OBJECTIVE: This continuing research program seeks to develop theory and algorithms for exploiting special structure in large-scale optimization models used by JWAC.

DoD KEY TECHNOLOGY AREA: Other (Design Automation)

KEYWORDS: Large-Scale Mixed Integer Programming

PUBLICATIONS/PRESENTATIONS

JOURNAL PAPERS

Brown, G., Bausch, D., and Ronen, D., "Scheduling Short-Term Marine Transport of Bulk Products," *Maritime Policy and Management*, 25-4, pp. 335-348, 1998.

Bradley, G. and Buss, A., "Dynamic, Distributed, Platform Independent OR/MS Applications—A Network Perspective," *INFORMS Journal on Computing*, Vol. 10, No. 4, pp. 384-387, Fall 1998.

Cormican, K., Morton, D., and Wood, K., "Stochastic Network Interdiction," *Operations Research*, 46, pp. 184-197, 1998.

Dell, R.F., "Optimizing Army Base Realignment and Closure," *Interfaces*, Vol. 28, No. 6, pp. 1-8, November/December 1998.

Gaver, D.P., Jacobs, P.A., and Dudenhoeffer, D.D., "Failure, Repair, and Replacement Analysis of a Navy Subsystem: Case Study of a Pump," *Applied Stochastic Models and Data Analysis*, 13, pp. 369-376, 1998.

Koyak, R.A., Schmehl, R.L., Cox, D.C., Dewalt, F.G., Haugen, M.M., Schwemberger, J.G., and Scalera, J.V., "Statistical Models for the Evaluation of Portable Lead Measurement TechnologiesæPart I: Chemical Test Kits," *Journal of Agricultural, Biological, and Environmental Statistics* (3), pp. 451-465, 1998.

Lucas, T., Bennett, B., Friel, J., and Kerchner, R., "ADS for Analysis: Much Agreement, Important Differences," *PHALANX*, December 1998.

Washburn, Alan R., "Orbital Dynamics for the Compleat Idiot," *Naval War College Review*, Vol. LII #1, 120-129, 1998.

CONFERENCE PAPERS

Buss, A. and Jackson, L., "Distributed Simulation Modeling: A Comparison of HLA, CORBA, and RMI," *Proceedings of the 1998 Winter Simulation Conference*, pp. 819-825, Washington, DC, 1998.

Brown, G., Bausch, D., and Ronen, D., "Scheduling Short-Term Marine Transport of Bulk Products," *Maritime Policy and Management*, 25-4, pp. 335-348, 1998.

Krebs, W.K., Scribner, D.A., Miller, G.M., Ogawa, J.S., and Schuler, J., "Beyond Third Generation: A Sensor Fusion Targeting FLIR Pod for the F/A-18," *Proceedings of the SPIE-Sensor Fusion: Architectures, Algorithms, and Applications II*, 3376, pp.129-140, 1998.

Krebs, W.K., Essock, E.A., Buttrey, S.E., and Sinai, M.J., "Chromatic Oblique Effect of Contrast Sensitivity," *Investigative Ophthalmology and Visual Science, (SUPPL)*, 39, 771, Fort Lauderdale, FL, 1998.

McDaniel, R., Scribner, D., Krebs, W., Warren, P., Ockman, N., and McCarley, J., "Image Fusion for Tactical Applications," *Proceedings of the SPIE - Infrared Technology and Applications XXIV*, 3436, pp. 685-695, 1998.

Newman, Alexandra M. and Yano, Candace A., "Optimizing Intermodal Rail Operations," *Proceedings of the 1998 Manufacturing and Service Operations Management Conference*, Seattle, WA, 29-30 June 1998.

Olwell, David H., "Information, Intelligence, Knowledge, and Combat Dynamics: A Meta-Model," *Proceedings of the 66th Military Operations Research Society Symposium*, Monterey, CA, 22 June 1998.

Page, E., Buss, A., Fishwick, P., Healy, K., Nance, R., and Paul, R., "The Modeling Methodological Impacts of Web-Based Simulation," *Proceedings of the 1998 International Conference on Web-Based Modeling & Simulation*, January 1998.

PUBLICATIONS/PRESENTATIONS

Shaw, Charles H., III, "Overview of SOF Modeling and Analysis in Support of the U.S. Special Operations Command (USSOCOM)," *Proceedings of the 66th Military Operations Research Society Symposium*, pp. 159, Monterey, CA, June 1998.

Taylor, J.G., Mansager, B.K., Buss, A.H., and Brown, R., "On The Theoretical Bases of the Attrition-Calibration (ATCAL) Method, with Applications to Algorithm Development," *Proceedings of the First National Meeting of the Military Applications Society*, Huntsville, AL, May 1998.

Taylor, J.G., "Mathematical Analysis of the Underlying Lanchester-Type Models for COMAN/ATCAL," *Proceedings of the First National Meeting of the Military Applications Society*, Huntsville, AL, May 1998.

CONFERENCE PRESENTATIONS

Baker, S.F., "NRMO Status Update," Air Force Air Mobility Modeling and Simulation User's Conference, Air Force Academy, May 1998.

Bilyeu, A. and Shaw, C.H., III, "Platform Independent, Distributed, Dynamic, Map-Based Military Planning and Analysis Systems for SOF," 66th Military Operations Research Society Symposium (MORSS), Monterey, CA, 23-25 June 1998.

Bradley, G., Buss, A., Bilyeu, A., and Arntzen, A., "Loosely Coupled Components - Architecture for Dynamic Map-Based Military Planning Systems Using Platform Independent Software Technologies," Air Force Office of Scientific Research - New World Vistas Project Review, Monterey, CA, 5 May 1998.

Bradley, G., "Tutorial: Java Introduction and OR Applications," 6th INFORMS Computer Science Technical Section Conference on Computer Science and Operations Research: Recent Advances in the Interface, Monterey, CA, 7-9 January 1998.

Bradley, G., "Architecture for Dynamic Map-Based Military Planning Systems Using Platform Independent Software Technologies," 2nd Center for Military Analysis/Naval Postgraduate School Meeting, Haifa, Israel, 2 July 1998.

Bradley, G., "Map-Based Dynamic Planning Systems in Java," INFORMS International, Tel Aviv, Israel, 28 June-1 July 1998.

Bradley, G., Buss, A., Bilyeu, A., and Jackson, L., "Demonstration: Platform Independent, Distributed, Dynamic, Map-Based Military Planning Systems," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

Bradley, G., Buss, A., and Shaw, C.H., III, "Loosely Coupled Components - Architecture for Dynamic Map-Based Military Planning, Analysis, Rehearsal, and Execution Systems Using Platform Independent Software Technologies," MPARE IPT Conference, Tampa, FL, 10-14 August 1998.

Buss, A. and Jackson, L., "Distributed Simulation Modeling: A Comparison of HLA, CORBA, and RMI," 1998 Winter Simulation Conference, Washington, D.C., 13-16 December 1998.

Byrne, P.C., Rosenthal, R.E., and Widdowson, B.L., "A Joint Service Optimization of the Phased Threat Distribution," 66th Military Operations Research Society Symposium, Monterey, CA, June 1998.

Curet, Norman D., Brandeau, John F., and Olson, A., "An Integer Programming Formulation for Estimating Hierarchical Levels in an Undirected Graph," CORS/INFORMS, Montreal, Canada, 28 April 1998.

Gaver, D.P. and Jacobs, P.A., "Controlling Service When Service Completion is Uncertain," INFORMS National Meeting, Montreal, Canada, 26-29 April 1998.

Israeli, E. and Wood, K., "Maximizing a Shortest Path," INFORMS National Meeting, Seattle, WA, 25-28 October 1998.

Lanquist, T. and Shaw, C.H., III, "Logistics Planning Factors for Special Operations Forces (SOF) Logistics Modeling and Simulation," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

Lawphongpanich, S., Seise, A, Thurman, J., and Yuengert, L., "Officer Modeling and Forecasting: A Network Approach," British-American Forecasting Exchange Conference, West Point, NY, 13-15 May 1998.

Lawphongpanich, S., "Simplicial and Truncated Dantzig-Wolfe Decomposition," INFORMS Conference, Seattle, WA, 25-28 October 1998.

Lucas, T., "The Warfighting Experiment Analytical Process—Where Do We Go From Here?" U.S. Army Conference on Applied Statistics (ACAS), Las Cruces, NM, October 1998.

Lucas, T, "Improving the Analytical Contribution of Advanced Warfighting Experiments," 2nd Center for Military Analysis/ Naval Postgraduate School Meeting, Haifa, Israel, July 1998.

Newman, Alexandra M. and Yano, Candace A., "Optimizing Intermodal Operations Over the Rail (Linehaul) Segment of Truck-Rail Intermodal Transportation," Institute for Operations Research and the Management Sciences Conference, Montreal, Canada, 26-29 April 1998.

Newman, Alexandra M. and Yano, Candace A., "Optimizing Intermodal Rail Operations," Manufacturing and Service Operations Management Conference, Seattle, WA, 29-30 June 1998.

Newman, Alexandra M. and Yano, Candace A., "Optimizing Intermodal Rail Operations," Institute for Operations Research and the Management Sciences Conference, Seattle, WA, 25-28 October 1998.

Morton, D. and Wood, K., "Optimistic Bounds for Stochastic Optimization," Prague Stochastics 98, Prague, Czech Republic, 23-28 August 1998.

Morton, D. and Wood, K., "Optimistic Monte Carlo Bounds for Stochastic Programming," VII International Conference on Stochastic Programming, University of British Columbia, Vancouver, Canada, 8-16 August 1998.

Morton, D. and Wood, K., "On a Stochastic Knapsack Problem and Generalizations," 6th INFORMS Computer Science Technical Section Conference, Monterey, CA, 6-9 January 1998.

Olwell, David H., "Predictive Control Methods for the Military," MORS Educational Colloquium, Crystal City, VA, 23 April 1998.

Olwell, David H., "Information, Intelligence, Knowledge, and Combat Dynamics: A Meta-Model," 66th Military Operations Research Society Symposium, Monterey, CA, 22 June 1998.

Olwell, David H., "Inference Based on Combat Simulations," 1998 Army Conference on Applied Statistics, Las Cruces, NM, 22 October 1998.

Olwell, David H., "A Reformed Web Delivered Statistics Course," 11th International Conference on Technology in Collegiate Mathematics, New Orleans, LA, 18 November 1998.

Olwell, David H., Avey, Mike, McCallum, Corbett, Miller, Kate, and Radicic, Adam, "The Effect of Attitude Towards Mathematics on Performance in Required and Elective Mathematics Courses," 11th International Conference on Technology in Collegiate Mathematics, New Orleans, LA, 18 November 1998.

Page, E., Buss, A., Fishwick, K., Healy, Nance, R., and Paul, R., "The Modeling Methodological Impacts of Web-Based Simulation," 1998 International Conference on Web-Based Modeling and Simulation, 11-14 January 1998.

Shaw, C.H., III, "Map-Based Dynamic Planning and Analysis Using Java and CORBA," Joint Mission Analysis (JMA) and MPARE Integrated Product Team (IPT) Conference, Tampa, FL, 2-6 February 1998.

Schrady, D.A., "Estimating the Economic Benefits of Forward-Engaged Naval Forces," Institute for Operations Research and the Management Sciences Conference, Montreal, Canada, 27-29 April 1998.

Schrady, D.A., Looney, R.E., and Brown, R.L., "Forward Engagement Requirements for U.S. Naval Forces: New Analytical Approaches," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

Schrady, D.A., "The Economic Benefits of Forward-Engaged Naval Forces," Military Operations Research Society Workshop on C4ISR, Carlisle Barracks, PA, 27-29 October 1998.

Shaw, C.H., III, "Overview of SOF Modeling and Analysis in Support of the U.S. Special Operations Command (USSOCOM)," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

Shaw, C.H., III, "Modeling Logistics in Full Spectrum Operations/Operations Other Than War (FSO/OOTW)," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

Taylor, J.G., Mansager, B.K., and Brown, R., "Redesign of ATCAL Attrition Algorithm for Military OR Problems in the Twenty-First Century," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

Taylor, J.G., "Initial Theoretical Evaluation of JWARS Ground-Combat Attrition Model," AMSO Attrition Meeting, Attrition Standards Coordinating Committee (SCC) of the Army Modeling and Simulation Office (AMSO), Aberdeen Proving Ground, MD, 15 December 1998.

Taylor, J.G., "Single-System Kill Rates by the Bonder-Farrell Approach," AMSO Attrition Meeting, Attrition Standards Coordinating Committee (SCC) of the Army Modeling and Simulation Office (AMSO), Aberdeen Proving Ground, MD, 15 December 1998.

Taylor, J.G., "Markov-Chain Models of Target Availability," AMSO Attrition Meeting, Attrition Standards Coordinating Committee (SCC) of the Army Modeling and Simulation Office (AMSO), Aberdeen Proving Ground, MD, 15 December 1998.

Taylor, J.G., Mansager, B.K., Buss, A.H., and Brown, R., "On The Theoretical Bases of the Attrition-Calibration (ATCAL) Method, With Applications to Algorithm Development," First National Meeting of the Military Applications Society, Huntsville, AL, 19-21 May 1998.

Taylor, J.G., "Mathematical Analysis of the Underlying Lanchester-Type Models for COMAN/ATCAL," First National Meeting of the Military Applications Society, Huntsville, AL, 19-21 May 1998.

Taylor, J.G., "Suggested Changes in the Integrated Theater Engagement Model (ITEM)," ITEM User's Group Meeting, San Diego, CA, 15 July 1998.

Tivnan, B.F., "Optimizing United States Marine Corps Enlisted Assignments," 66th Military Operations Research Society Symposium, Monterey, CA, 23-25 June 1998.

PUBLICATIONS/PRESENTATIONS

Washburn, Alan R., "Issues for Minefield Clearance Models," Symposium on Technology and the Mine Problem, Monterey, CA, April 1998.

Washburn, Alan R., "Solving Large-scale Allocation Problems with Imperfect Costly Battle Damage Assessment," New World Vistas Review, Monterey, CA, May 1998.

Washburn, Alan R., "Bits, Bangs, or Bucks: the Coming Information Crisis," 66th Military Operations Research Society Symposium, Monterey, CA, June 1998.

Williams, L., "Generalized Network Enlisted Forecasting Model," British-American Army Forecasting Exchange Conference, West Point, NY, May 1998.

TECHNICAL REPORTS

Baker, S.F. and Rosenthal, R.E., "A Cascade Approach for Staircase Linear Programs," Naval Postgraduate School Technical Report, NPS-OR-98-004, July 1998.

Gaver, D.P., Jacobs, P.A., and Youngren, M.A., "Analytical Models for Battlespace Information War (BAT-IW) Part 1," Naval Postgraduate School Technical Report, NPS-OR-98-001, February 1998.

Gaver, D.P. and Jacobs, P.A., "Suppression of Enemy Air Defense (SEAD) as an Information Duel," Naval Postgraduate School Technical Report, NPS-OR-98-005, August 1998.

Gaver, D.P., Jacobs, P.A., and Stoneman, J., "Analytical Models for Mobile Sensor (UAV) Coverage of a Region," Institute for Joint Warfare Analysis Technical Report, Naval Postgraduate School, May 1998.

Gaver, D.P. and Jacobs, P.A., "Assessing and Controlling the Availability of Failure-Degraded Service Agents," Naval Postgraduate School Technical Report, NPS-OR-98-002, May 1998.

Jacobs, P.A. and Gaver, D.P., "Human Factors Influencing Decision Making," Naval Postgraduate School Technical Report, NPS-OR-98-003, July 1998.

Kerman, C.K., Brown, G., and Dell, R., "Optimally Reorganizing Navy Shore Infrastructure," Naval Postgraduate School Technical Report, NPS-OR-98-006, August 1998.

Read, R. R., "Summary of the Reliability and Maintainability Research Relating to the Joint Strike Fighter Program," Naval Postgraduate School Technical Report, NPS-OR-98-007, October 1998.

Schrady, D.A., "Combatant Logistics Command and Control for the Joint Force Commander," Naval Postgraduate School Technical Report, NPS-IJWA-98-001, January 1998.

BOOKS

Hawkins, Douglas and Olwell, David, *Cumulative Sum Charts and Charting for Quality Improvement*, New York: Springer, 1998.

CONTRIBUTION TO BOOKS

Morton, D. and Wood, K., "On a Stochastic Knapsack Problem and Generalizations," *Advances in Computational and Stochastic Optimization, Logic Programming, and Heuristic Search: Interfaces in Computer Science and Operations Research*, D.L. Woodruff, (ed.), pp. 149-168, 1998.

Read, R.R., "Errors of the First and Second Kinds," *Encyclopedia of Industrial Engineering*, A. Mital, (ed.), 1998.

OTHER

Bradley, G., SOFLCC: A system to support real-time and near real-time decision making for Special Operations Forces using network models based on the Loosely Coupled Components Architecture (LCCA).

Koyak, Robert, A., Testimony and Statement before the U.S. House Committee on Government Reform and Oversight, Subcommittee on the Census, 17 September 1998.

Shaw, C.H., III, Software deliverables to the United States Special Operations Command (USSOCOM) included the Special Operations Forces Logistics Planner (SOFLOGPLNR) programs for each Service component and the Special Operations Forces Loosely Coupled Components Planning and Analysis Program (SOFLCC Program).

AN EVALUATION OF MARKOV CHAIN MODELING
FOR F/A-18 AIRCRAFT READINESS

Leigh P. Ackart-Lieutenant Commander, Supply Corps, United States Navy
B.S., Southern Illinois University, 1987
Master of Science in Operations Research-September 1998
Advisor: Lyn R. Whitaker, Department of Operations Research
Second Reader: Kevin J. Maher, Department of Operations Research

During its 1998 deployment the USS INDEPENDENCE (CV 62) and Carrier Air Wing Five operated under the control of Commander, Task Force 50 (CTF-50). To balance resources and readiness, CTF-50 asked the following question: "How many days can the USS INDEPENDENCE go without 'off ship' logistics support before the number of Mission Capable aircraft can be expected to fall below Chief of Naval Operations (CNO) readiness goals?" This thesis develops a Markov chain model to answer this question. Explanatory variables for this model include sorties flown, cannibalization rate and frequency of "off ship" logistics support. Using data from the USS INDEPENDENCE this thesis analyzes the readiness by estimating the number of F/A-18 aircraft capable of performing at least one of its intended missions.

Both non-linear Markov models and Generalized Linear Models are employed to estimate the effect of the operating environment on the number of mission capable aircraft available. The analysis demonstrates how the Markov approach captures the cyclic nature of aircraft operations and maintenance. Specifically, it is shown that the USS INDEPENDENCE can expect to operate 5 – 8 days without "off ship" logistics support before F/A MC rates fall below CNO readiness goals. Recommendations for further studies are included.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Aviation Readiness, Markov Chain Models, Logistics Support, Carrier Onboard Delivery (COD)

AN OPTIMIZATION-BASED DECISION SUPPORT MODEL FOR THE NAVY
H-60 HELICOPTER PREVENTIVE MAINTENANCE PROGRAM

Michael H. Albright-Commander, United States Navy
B.S., Florida State University, 1980
Master of Science in Operations Research-September 1998
Advisor: Gerald G. Brown, Department of Operations Research
Second Reader: Ronald L. Brown, Department of Operations Research

For Naval aircraft, the largest portion of Operating and Support (O&S) costs is consumed by maintenance. The effort to reduce O&S costs is part of a Naval Air Systems Command initiative termed Affordable Readiness. Innovative programs are being implemented under Affordable Readiness to maintain safety, sustain readiness, and reduce costs.

One program, Integrated Maintenance Concept (IMC), is being developed for the Navy H-60 helicopter. IMC calls for depot-level artisans to be collocated at each squadron facility rather than at a central facility. Integrating appropriate organizational level maintenance tasks with germane subsets of the depot level tasks is the essence of the H-60 IMC. Reduced aircraft maintenance costs and out-of-service time are the major benefits of IMC.

As part of the transition to IMC, current organizational, intermediate and depot maintenance requirements are being reviewed for applicability and effectiveness. The result of this review will be a new listing of justified preventive mainte-nance tasks. The tasks then are grouped in an optimal manner that minimizes total aircraft out-of-service time.

This thesis explores the potential synergism inherent to certain preventive maintenance task groupings that can lead to an overall reduction in aircraft out-of-service time. A prototypic optimization-based decision support model is developed. The solution presented is evaluated in terms of total cost in hours to perform all required tasks over a given time horizon. Additionally, the optimal task groupings are identified. Together, these results are insightful for developing a preventive maintenance program.

OPTIMIZING AMMUNITION MOVEMENT IN SUPPORT OF THE U.S. PACIFIC FLEET'S POSITIONING PLAN

Eric B. Anderson-Lieutenant Commander, United States Navy
B.S., University of North Carolina, 1987
Master of Science in Operations Research-September 1998
Advisor: John F. Raffensperger, National Research Council Post-Doctoral Associate
Second Reader: Douglas J. MacKinnon, Department of Operations Research

To support United States national and military strategy, the United States Navy must position ammunition at bases located in regions of potential conflict. The Commanders in Chief, U.S. Pacific Fleet (CINCPACFLT), U.S. Atlantic Fleet (CINCLANTFLT), and U.S. Naval Forces Europe (CINCUSNAVEUR) are responsible for developing positioning plans, in consultation with the Naval Ordnance Center (NAVORDCEN), to strategically position appropriate types and quantities of ordnance to support the warfighter and to meet both peacetime and wartime requirements. This thesis examines ammunition positioning in the Western Pacific. Changes to the positioning plan change the mix of ammunition types required to be stored at various bases. In order to satisfy the new requirements, ammunition must be relocated. There is not presently enough ammunition available to satisfy all requirements, so the relocation of available assets must be prioritized. This thesis discusses a model developed to optimize the ordnance positioning and transportation options. The model is used to better locate current stocks of ammunition in order to satisfy the CINCPACFLT Ammunition Positioning Plan.

SOFTWARE COMPONENTS FOR AIR DEFENSE PLANNING

Arent Arntzen-Royal Norwegian Air Force
Master of Science in Operations Research-September 1998
Advisor: Arnold H. Buss, Department of Operations Research
Second Reader: Gordon H. Bradley, Department of Operations Research

Modern offensive weapon technologies such as stealth and precision guided munitions have rendered Integrated Air Defense Systems increasingly vulnerable and ineffective. Stealth effectively reduces the performance of radar, but does not have the same impact on passive systems. Sensors have been the most important and vulnerable part of air defense systems throughout the history of air warfare. Research into passive sensors has been encouraging, but before passive sensor systems are produced, procured and deployed, analysis and planning must be conducted to quantify potential benefit and determine feasible system configurations. As this type of analysis encompasses extremely complex system behavior, developing reusable and flexible simulation models becomes important. This thesis develops a prototype software component architecture and component library for building simulation models for air defense analysis. Sensor and airborne weapon simulation components are demonstrated and used in an exploratory analysis of the impact of a network of Infrared Search and Track sensors. The analysis is based on a modern air defense system deployed in a realistic scenario. The component architecture and documentation methodology supports reuse, and provides model configuration flexibility with potential for growth in successive stages of analysis.

OPTIMAL LONG-TERM AIRCRAFT CARRIER DEPLOYMENT PLANNING WITH SYNCHRONOUS DEPOT LEVEL MAINTENANCE SCHEDULING

Mehmet Ayik-Lieutenant, Turkish Navy
B.S., Turkish Naval Academy, 1992
Master of Science in Operations Research-March 1998
Advisor: Gerald G. Brown, Department of Operations Research
Second Reader: Ronald L. Brown, Department of Operations Research

Forward deployment of Navy aircraft carrier battle groups is a primary means for the United States to achieve overseas interests. The Navy maintains the forward presence of aircraft carriers in three major Areas of Responsibility (AORs): the Mediterranean Sea, the Persian Gulf, and the Western Pacific. Considering the cost of carrier operations and the desire to maximize coverage of the AORs, planning deployments for the carriers not only significantly affects the achievement of U.S. defense strategy, but also impacts the Navy financially. Previous studies have maximized the deployment of aircraft carriers to the AORs while strictly adhering to the fixed, long-range maintenance schedules published by the Planning and Engineering for Repairs and Alterations Activity for Aircraft Carriers (PERA CV). This thesis optimizes aircraft carrier deployment planning while shifting the pre-scheduled maintenance availabilities well within limits allowed by the Chief of Naval Operations (CNO). This synchronous planning of deployments and major maintenance yields at least 15% more planned coverage in the AORs with the existing carrier fleet. Such an increase had heretofore been thought to require three additional aircraft carriers.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Surface/Undersurface Vehicles – Ships and Watercraft, Modeling and Simulation, Other (Optimization)

KEYWORDS: Aircraft Carriers, Deployment Planning, Depot Level Maintenance, Crisis Response Times, Coverage of Areas of Responsibility, Optimization

CLIMATE SURVEY ANALYSIS FOR AVIATION MAINTENANCE SAFETY

Robert H. Baker-Captain, United States Marine Corps
B.S., United States Naval Academy, 1991
Master of Science in Operations Research-September 1998
Advisors: Robert R. Read, Department of Operations Research
CDR John K. Schmidt, School of Aviation Safety
Second Reader: Lyn R. Whitaker, Department of Operations Research

Naval Aviation has been challenged to cut its 1996 human factors related Class A flight mishap rate in half by the year 2000. Investigations show that human caused flight mishaps have not declined as rapidly as mechanical ones. From fiscal year 1990 through 1997, maintenance was a causal factor in 17 percent of Class A flight mishaps. Presently, there is an ongoing effort to identify factors contributing to human error in aviation maintenance. One major component is the development of an instrument to assess safety climate and posture in maintenance operations. This thesis is the climate safety assessment portion of this effort. It utilizes and adapts an existing Model of Organizational Safety Effectiveness (MOSE) to achieve an understanding of the possible influences of organizational factors on aviation maintenance. This thesis develops and administers a prototype Maintenance Climate Assessment Survey (MCAS) that provides a tool for assessing safety in maintenance operations. The study has 268 participants from three Reserve squadrons that represent the spectrum of aviation communities. The prototype MCAS is comprised of 67 questions developed from 155 candidate questions. Each question uses a Likert type rating scale, which allows participants to express opinions for each item presented. Cluster and Factor analysis is used to identify redundancies between items and how items clustered according to the MOSE components. The product of this study is a finalized MCAS with 35 questions that can be used by the Squadron command and Aviation Safety Officer to assess their unit's safety posture in conducting scheduled/unscheduled maintenance operations.

ON THE QUASIMONOTONICITY OF A SQUARE LINEAR OPERATOR WITH RESPECT TO A NONNEGATIVE CONE

Philip Beaver-Major, United States Army
B.S., United States Military Academy, 1983
M.S., Naval Postgraduate School, 1991
Doctor of Philosophy in Applied Mathematics-June 1998
Advisor: David Canright, Department of Mathematics
Committee: Christopher L. Frenzen, Department of Mathematics
Robert F. Dell, Department of Operations Research
Clyde L. Scandrett, Department of Mathematics
Maurice D. Weir, Department of Mathematics

The question of when a square, linear operator is quasimonotone nondecreasing with respect to a nonnegative cone was posed for the application of vector Lyapunov functions in 1974. Necessary conditions were given in 1980, which were based on the spectrum and the first eigenvector. This dissertation gives necessary and sufficient conditions for the case of the real spectrum when the first eigenvector is in the nonnegative orthant, and when the first eigenvector is in the boundary of the nonnegative orthant, it gives conditions based on the reducibility of the matrix. For the complex spectrum, in the presence of a positive first eigenvector the problem is shown to be equivalent to the irreducible nonnegative inverse eigenvalue problem.

CONCEPT FOR A SPECIAL OPERATIONS PLANNING AND ANALYSIS SYSTEM

Allan L. Bilyeu-Captain, United States Army
B.S., United States Military Academy, 1987
Master of Science in Operations Research-June 1998
Advisor: Gordon H. Bradley, Department of Operations Research
Second Reader: Charles H. Shaw, III, Department of Operations Research

This thesis designed and partially implemented a platform independent mission planning and analysis system for the United States Special Operations Command (US SOCOM). The ability to move to platform independent technologies is particularly important for the special operations community since it cannot expect standardized computer planning and analysis systems for their joint, multi-national, and inter-agency operations. This thesis also investigates the ability to integrate legacy systems using an open architecture on an object web. In addition, this thesis incorporates operations research methods into this system to show their importance in planning and analysis. The system is developed in the Java programming language using loosely coupled components. The system involves an image component that contains a map with overlays. The use of common object request broker architecture (CORBA) for integrating legacy systems is discussed. To show the relevance of this system, a scenario involving joint and coalition forces is developed. The scenario demonstrates the usefulness and need for platform independent planning and analysis systems. Finally, this thesis recommends an architecture that USSOCOM should investigate for its future mission planning, analysis, rehearsal, and execution (MPARE) system.

PARTIAL-ENUMERATION FOR PLANAR NETWORK INTERDICTION PROBLEMS

Michael R. Boyle-Lieutenant, United States Navy
B.S., University of Illinois, 1988
Master of Science in Operations Research-March 1998
Advisor: R. Kevin Wood, Department of Operations Research
Second Reader: Gerald G. Brown, Department of Operations Research

In the network interdiction problem, an interdictor destroys a set of arcs in a capacitated network through which an adversary will maximize flow. The interdictor's primary objective is to use his limited resources to minimize that maximum flow, but other objectives may be important. Therefore, we describe algorithms for enumerating near-optimal interdiction sets in planar networks so that these sets may be evaluated with respect to secondary criteria, e.g., safety of attacking forces, collateral damage, etc. The algorithms are based on enumerating near-shortest paths or cycles in the dual of a planar network; they find a single optimal interdiction set in pseudo-polynomial time. One algorithm was implemented applicable to s-t planar networks (s and t must lie on the perimeter of the network) and solve problems with up to 512 nodes and 791 arcs. An example of computational results on that largest network is that the algorithm enumerates all 959 solutions that are within 10% of optimal in 3.46 seconds on a 133 mHz Pentium PC. It was also proposed, but not implemented, at a somewhat less efficient extension of this algorithm to solve problems on general planar networks.

A RELIABILITY AND AVAILABILITY ANALYSIS OF NOTIONAL JOINT STRIKE FIGHTER AIRCRAFT DESIGNS

Daniel E. Boyles-Lieutenant Commander, United States Navy
B.S., University of Illinios, 1986
Master of Science in Operations Research-September 1998
Advisor: Robert R. Read, Department of Operations Research
Second Reader: Lyn R. Whitaker, Department of Operations Research

This thesis investigates the reliability and availability differences of notional Aircraft Carrier Takeoff and Landing (CVTOL) and Short Takeoff and Vertical Landing (STOVL) versions of the Joint Strike Fighter (JSF) aircraft using basic Reliability Block Diagrams (RBD), survivor functions, and stochastic methods. The models used in this thesis can be developed for forecasting the reliability and availability of any notional aircraft. The aircraft component data were extracted from the Naval Aviation Logistics Data Analysis (NALDA) database. Stochastic model sensitivity analysis of critical notional aircraft components and comparison of aircraft survivor function calculations indicate the STOVL JSF has a higher attrition rate and a significantly lower availability than the CVTOL JSF.

AN ALGORITHM FOR CLASSIFYING PUBLIC SWITCHED TELEPHONE NETWORKS (PSTN) SWITCHING STATIONS

John F. Brandeau-Commander, United States Navy
B.S., Duke University, 1980
Master of Science in Operations Research-September 1998
Advisor: Robert F. Dell, Department of Operations Research
Second Reader: Norman D. Curet, National Security Agency

The National Security Agency (NSA) collects and processes signals intelligence information for national security purposes. As part of this mission, NSA predicts message routing over public switched telephone networks (PSTNs). The hierarchical switching level (or classification) of PSTN switching stations must be determined before making routing predictions. This thesis develops a fast graph-theoretic algorithm for accomplishing this classification. An undirected connected graph models a target PSTN; switching stations are nodes and logical connections between the switching stations are unit-length arcs. We develop bounds for the minimum number of switching levels and implicitly enumerate all possible classifications for each PSTN. The algorithm is implemented in Java and PSTNs are classified using a personal computer. Solutions are obtained in under one second for nine real-world PSTNs, and large notional networks of over 300 nodes and 900 arcs are classified in under one minute. This research improves existing node classification software.

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

KEYWORDS: Public Switched Telephone Network, PSTN, Hierarchical PSTN, Telecommunications, Java, Graph Theory, National Security

A PROCESS SIMULATION DESIGN TO ASSESS PROMISING TECHNOLOGIES RELEVANT TO F/A-18 AIRCREW TARGET RECOGNITION

Eric V. Bryant-Major, United States Marine Corps
B.S., San Diego State University, 1985
Master of Science in Information Technology Management-September 1998
Advisors: William K. Krebs, Department of Operations Research
Terrance C. Brady, Department of Systems Management

F/A-18 aircrew visual target recognition during air-to-ground weapons employment is accomplished by the integration of sensors, systems, and information processing by the aircrew. The aircrew's ability to rapidly obtain target recognition from the cockpit display of the target scene is critical to accurate weapons delivery.

Using system engineering principles, a process simulation design was devised consistent with DoD acquisition reform regulations, that simulates how aircrew perform visual search and target recognition in attack aircraft, and it provides measures of performance (MOP) for decision-makers to assess the effectiveness of promising technologies. Two assessments were performed. The first experiment measures for effect in aircrew target recognition reaction time and accuracy using two different sensors – visible and infrared. An analysis of variance (ANOVA) of the measured reaction times data showed that aircrew using a visible sensor were significantly faster than aircrew using an infrared sensor. The second assessment involves aircrew cognitive model building during pre-mission planning using Mission Rehearsal Simulation (MRS) software. An ANOVA of the measured data revealed that aircrew who used the MRS software was significantly faster than aircrew who did not. An optimum aircrew training methodology using MRS software was devised and it is currently being integrated into F/A-18 fleet replacement squadron training.

DoD KEY TECHNOLOGY AREAS: Human Systems Interface, Sensors, Modeling and Simulation, Other (Defense Acquisition, Systems Engineering)

KEYWORDS: Target Recognition, Human Factors, Simulation, Process Decomposition

COORDINATED INLAND AREA SEARCH AND RESCUE (SAR) PLANNING AND EXECUTION TOOL

Timothy S. Castle-Lieutenant, United States Coast Guard
B.S., United States Coast Guard Academy, 1991
Master of Science in Operations Research-September 1998
Advisors: Gordon Bradley, Department of Operations Research
Alan Washburn, Department of Operations Research
Second Reader: James Eagle, Undersea Warfare Academic Group

This thesis designs and implements the Coordinated Inland Area Search and Rescue (SAR) System (COINSS). This system provides several important features not provided by current inland SAR computer systems. First is the ability to model movement of the target. Second is modeling the effect terrain has on the movement of the target. Third is the visual presentation of a probability map, a color display showing the probability that the target is located at various geographic positions. COINSS is developed in the Java programming language. It is designed to be implemented with a map-based planning system using loosely coupled components. COINSS provides the initialization, movement, and search algorithms which are used by the planning system to support the search operation. The initialization algorithms define the search area where the SAR operation will occur. Initial areas are defined for the target. COINSS models the movement of the target as a discrete time Markov chain. Bayes theorem is used to update the probability map when negative search information is provided. This thesis will improve inland SAR operations by providing the first model with an interactive graphical user interface and a model of target movement.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Search and Rescue, Java, Loosely Coupled Components, Map Based Planning

MAP USAGE IN VIRTUAL ENVIRONMENTS

Helsin Cevik-Lieutenant Junior Grade, Turkish Navy
B.S., Turkish Naval Academy, 1992
Master of Science in Computer Science-September 1998
Advisors: Rudolph Darken, Department of Computer Science
John Falby, Department of Computer Science
Second Reader: Dylan Schmorrow, Department of Operations Research

It is neither practical nor efficient to represent virtual maps as we do for paper maps in the real world due to major differences in hardware and software capabilities and requirements. Instead, the parameters can be determined that affect virtual map representation and that help to construct a mental map, and then manipulate these parameters in order to increase the effectiveness of map representation as an aid in performing navigation tasks.

The approach taken was first to determine and then investigate the parameters that affect virtual map representation through an experiment designed specifically for this thesis. The experiment examined users of an urban and open ocean virtual environment executing a set of navigation tasks with a virtual map with different orientation schemas.

The results of this study showed that, a forward-up map orientation is preferable to a north-up map orientation for egocentric tasks and a north-up map orientation is preferable to a forward-up map orientation for geocentric tasks. Under almost every possible condition, individuals with high spatial abilities will be able to use either a north-up map or a forward-up map better than individuals with low spatial abilities. Furthermore, it was found that these principles apply across types of environment with vastly different spatial characteristics, but sparse environments seem to exhibit less of a performance difference than dense environments.

DoD KEY TECHNOLOGY AREAS: Human Systems Interface, Modeling and Simulation

KEYWORDS: Virtual Environments, Wayfinding, Navigation, Virtual Maps, Spatial Visualization, Spatial Orientation, Cognitive Maps, Mental Rotation

MINIMIZING ARMY CADET TEMPORARY DUTY

Clay S. Chilson-Lieutenant, United States Navy
B.S., United States Naval Academy, 1992
Master of Science in Operations Research-March 1998
Advisor: Robert F. Dell, Department of Operation Research
Second Reader: LTC Charles H. Shaw, Department of Operations Research

Every newly-commissioned Army officer from a Reserve Officer Training Corps (ROTC) commissioning source joins one of 19 different basic branches (e.g., infantry, armor) and undergoes initial training to develop fundamental skills at an Officer Basic Course (OBC). Each basic branch has a separate training program and offers multiple OBC classes every year. The Army grants commissions to approximately 3,000 ROTC cadets annually and, under the current system, manually schedules each cadet to attend an OBC class. In addition, the Army schedules approximately 850 of these cadets to fill one of two temporary duty (TDY) assignments en route to their OBC class. This thesis develops a mixed integer linear program called Minimizing Cadet Temporary Duty (MCTDY) to reduce the time needed to schedule cadets and reduce the TDY costs as well as pay and allowances incurred by all second lieutenants prior to their OBC class. For 2,828 cadets receiving commissions in 1998, MCTDY produces face-valid, cost-effective results. Direct comparisons between MCTDY and manual schedules are not made but experiments with MCTDY indicate a difference in TDY costs of up to $15 million is possible.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Personnel Scheduling, Army ROTC, Officer Basic Course, Mixed Integer Linear Programming

A COMPARISON OF THE FORCE DEPLOYMENT ESTIMATOR (FDE) AND NAVAL POSTGRADUATE SCHOOL / RAND MOBILITY OPTIMIZER (NRMO) AS TOOLS FOR MOBILITY ANALYSIS

Eric M. Damm-Major, United States Marine Corps
B.S., Pennsylvania State University, 1984
Master of Science in Operations Research-September 1998
Advisors: Richard E. Rosenthal, Department of Operations Research
Laura M. Williams, Department of Operations Research
Second Reader: Lt Col Kirk Yost, Department of Operations Research

Over the past decade, changes in the global power structure have driven the United States into a major reassessment of its force structure and global force projection requirements. There is a resulting need for force deployment models that offer quick, accurate analysis of force projection options and proposed force structure changes. One model, the Force Deployment Estimator (FDE), a combination discrete event simulation and goal program, is currently used by the J8, Warfighting Analysis Division (J8/WAD). A second model with similar capabilities, the Naval Postgraduate School/RAND Mobility Optimizer (NRMO), is a linear program that was written for the Air Force Studies and Analysis Agency. In order to compare the two models and give J8/WAD the option of a second model for use in analysis, NRMOAS (NRMO Air/Sea) was created by adding a sealift component to NRMO. NRMOAS creates both an air and sea network and can be run with the user designating the unit's mode of travel, the model determining the same or a combination of both. This thesis compares the results of several different scenarios run through FDE and NRMOAS. In all cases, NRMOAS out performed FDE in terms of timely delivery of personnel and cargo. Additionally, NRMOAS allows a far higher level of resolution in network structure. The recommendation is that NRMOAS be used by J8/WAD for detailed mobility analysis. Also recommended are changes to FDE.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (Optimization)

KEYWORDS: Mobility, Optimization, Force Deployment

SUBMARINE PERISCOPE DEPTH COURSE SELECTION TACTICAL DECISION AID

D.J. Danko-Lieutenant, United States Navy
B.S.E., University of Washington, 1990
Master of Science in Operations Research-December 1997
Advisor: Alan R. Washburn, Department of Operations Research
Second Reader: James N. Eagle, Undersea Warfare Academic Group

Coming to periscope depth is one of the most intensive of the routine submarine operations. Errors in fire control and sonar system information serve to produce uncertain contact solutions that complicate the decision of selecting a safe course. The model developed in this thesis simulates a specified number of trials on each possible course, with the measure of effectiveness for each course being the probability of the course being acceptable with respect to specified minimum range criteria. The model outputs a geographic display and a graph of the measures of effectiveness versus course.

KEYWORDS: Submarine Periscope Depth Operations, Course Selection, Tactical Decision Aid, Simulations Using Visual Basic Programming

DoD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles-Ships and Watercraft Ground Vehicles

THE ARSENAL SHIP CONCEPT: VULNERABILITIES TO SPECIAL OPERATIONS

Christian A. Dunbar-Lieutenant, United States Navy
B.S., University of Notre Dame, 1993
Master of Science in Defense Analysis-June 1998
and
Dino Pietrantoni-Lieutenant, United States Navy
B.S., United States Naval Academy, 1991
Master of Science in Defense Analysis-December 1997
Advisor: Wayne P. Hughes Jr., Department of Operations Research
Second Reader: Gordon H. McCormick, Special Operations/Low Intensity Conflict Curriculum Committee

The United States Navy has solicited proposals for a revolutionary class of ship, the Arsenal Ship. Despite reduced funding for the project, the concept is still viable for future development. We show how the development of a new unparalleled weapon system or platform will evoke a response by potential adversaries, based on capabilities and asset investment, by unconventional means. The Arsenal Ship is a target across the spectrum of conflict. This thesis will describe threats that are usually overlooked and examine the Arsenal Ship's vulnerability to them. In addition, we will show how these vulnerabilities arise as the Arsenal Ship operates through the range of geographic areas. Further, this thesis describes possible strategic and tactical defensive actions to enable the Arsenal Ship to counter these unconventional threats. Each recommended action has a direct implication upon the engineered design and the proposed Concept of Operations (CONOP). In addition, the recommendations will influence the strategy for employing any furthure platform based on the Arsenal Ship concept, anywhere in the world

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Command, and Control Communications, Conventional Weapons, Surface/Under Surface Vehicles-Ships and Watercraft

KEYWORDS: Arsenal Ship, ARSHIP, Maritime Special Operations, and Special Operations, Combat Swimmer, VBSS, Visit Board Search and Seize, Unconventional Warfare

SOPITE SYNDROME IN OPERATIONAL FLIGHT TRAINING

David E. Flaherty-Lieutenant Commander, United States Naval Reserve
B.S., Massachusetts Maritime Academy, 1985
Master of Science in Operations Research-September 1998
Advisors: CDR John K. Schmidt, School of Aviation Safety
Robert R. Read, Department of Operations Research
Second Reader: Samuel E. Buttrey, Department of Operations Research

Sopite Syndrome is a poorly understood response to motion characterized by drowsiness, fatigue, sleep disturbances, and mood changes. It is distinct from "regular" motion sickness or common fatigue, and may affect the performance of motor vehicle as well as aircraft operators. The potential impact Sopite Syndrome may have on military aviation is relatively unknown. Recently, research in situations relevant to aviation training and flight operations has been initiated. The present study is part of that effort. Its goal is to determine the incidence, severity, and association of Sopite Syndrome characteristics in a population of Student Naval Flight Officers (SNFOs). Seventy-eight SNFOs assigned to Training Squadrons Four and Ten located at the Naval Air Station Pensacola, Florida completed a questionnaire designed to capture evidence/incidence of fatigue, motion sickness, drowsiness, and sleep disturbances during days when SNFOs flew versus non-flying days.

The questionnaire data was coded/tabulated for entry on a spreadsheet for subsequent analysis. Descriptive and nonparametric statistical techniques were used to analyze the data set obtained. The results show sufficient evidence between the levels of symptomology and their relationships when comparing conditions that support the existence of Sopite Syndrome in operational flight training.

DoD KEY TECHNOLOGY AREA: Other (Human Factors)

KEYWORDS: Sopite Syndrome, Motion Sickness

THE EFFECTS OF SOPITE SYNDROME ON SELF-PACED AIRSICKNESS DESENSITIZATION PROGRAM

Michelle A. Flaherty–Lieutenant, United States Navy
B.S., Auburn University, 1988
M.A., National University, 1994
Master of Science in Operations Research-September 1998
Advisors: CDR John K. Schmidt, School of Aviation Safety
Robert R. Read, Department of Operations Research
Second Reader: Samuel E. Buttrey, Department of Operations Research

The U.S. Navy implemented the Self-Paced Airsickness Desensitization (SPAD) program in 1989 for aviation students whose incidence of airsickness was not easily resolved. Some participants may have also experienced symptoms that are not typically recognized as motion sickness, including prolonged drowsiness and/or mood changes. These effects are part of a poorly understood response to motion termed "Sopite Syndrome." This thesis explores the effects of Sopite Syndrome on student aviators diagnosed with motion sickness. Sixty SPAD program participants completed a survey comprised of scales, which estimate motion sickness, drowsiness, fatigue, and sleep disturbances during SPAD treatment days. Results indicate: (1) symptoms consistent of Sopite Syndrome were reported by 45% of the participants and (2) the presence of Sopite Syndrome in a SPAD participant was not an accurate predictor for successful treatment and return to flight status.

DoD KEY TECHNOLOGY AREA: Other (Human Factors)

KEYWORDS: Sopite Syndrome, Motion Sickness, Airsickness, Airsickness Rehabilitation Programs

NAVAL SPECIAL WARFARE LOGISTIC PLANNING SYSTEM

Michael F. Giancatarino-Commander, United States Navy
B.S., United States Naval Academy, 1981
M.S., Boston University, 1994
Master of Science in Operations Research-September 1998
Advisor: David A. Schrady, Department of Operations Research
Second Reader: LTC Charles H. Shaw, Department of Operations Research

In today's world, small-scale contingencies and operations-other-than-war have replaced major theater war as the driving United States (U.S.) military scenario and account for approximately 80% of operational tempo. Special Operations Forces play the key role in these limited actions. Similarly, the number of possible locations and levels of conflict have also increased. With the drawdown of permanent U.S. military bases throughout the world, the resulting reduction in logistic support has evolved as a major problem. Logistic support of naval special operations forces has not kept pace with this changing environment. An accurate and timely logistic planning aid is needed to assist in mission planning. Such a planning aid must utilize logistic planning factors for all classes of supply derived from conventional military sources, as well as, naval special warfare sources. These logistic planning factors are the input for the subsequent EXCEL, spreadsheet program designed to serve as a stand-alone, logistic requirement planning aid. This program can be used by naval special warfare staff, joint staff, and other mission planners to quickly calculate logistic supply and service requirements for a multitude of naval special warfare missions, area of operations, and threats.

DoD KEY TECHNOLOGY AREA: Other (Logistics)

KEYWORDS: Naval Special Warfare Forces, Logistic Planning Factors, Logistic Planning Requirements

SPATIAL KNOWLEDGE ACQUISITION AND TRANSFER FROM VIRTUAL TO NATURAL ENVIRONMENTS FOR DISMOUNTED LAND NAVIGATION

Simon R. Goerger-Captain, United States Army
B.S., United States Military Academy, 1988
Master of Science in Computer Science-September 1998
Advisors: Rudolph Darken, Department of Computer Science
Dylan Schmorrow, Department of Operations Research

Navigation and terrain familiarity are critical for mission success in the military. Virtual environments (VEs) have often been suggested as a useful tool in addressing these issues. This thesis research addresses the utility of VEs to improve spatial knowledge of and navigation performance through natural terrain compared to traditional methods. In this experiment, fifteen subjects were assigned to one of three training conditions. The map group studied the environment using only an orienteering map. The real world group studied the environment using the map and explored the actual terrain. The VE group studied the terrain using both the map and a real-time VE. Measures were taken of both route and configuration knowledge. The results suggest four conclusions. First, training conditions have no statistically significant effect on an individual's ability to obtain and demonstrate spatial knowledge of a natural environment. Second, spatial ability plays a significant role in navigation performance. Third, exposure to the actual terrain or to a virtual representation of the terrain seems to eliminate ambiguities in an individual's mental map by providing dynamic imagery to clarify propositional knowledge gained from maps. However, this factor has not been shown to improve performance by the measures used here. Fourth, a high resolution 1:5,000 orienteering map provides extensive detail and consequently, navigation performance in this experiment is not likely to be indicative of performance using a conventional 1:24,000 map.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Spatial Knowledge, Virtual Environments, Navigation, Orienteering, Geographic Information Systems, Terrain Visualization, Modeling and Simulation

PATRIOT PAC-3 MULTI-FUNCTION SIMULATION ANALYSIS:
A TIME SERIES APPROACH TO A DETERMINISTIC MODEL (U)

Omar F. Gutierrez-Captain, United States Army
B.S., United States Military Academy, 1989
Master of Science in Operations Research-September 1998
Advisor: George Conner, Department of Operations Research
Second Reader: Samuel Parry, Department of Operations Research

Defenses against tactical ballistic missile attacks are a primary national security need. The last line of defense against missiles in terminal phase is the next-generation PATRIOT (PAC-3) air defense system.A PAC-3 radar simulation called Multi-function Simulation (MFSIM) is undergoing the Army Verification, Validation and Accreditation Process. This model builds on a previous Patriot simulation.

This thesis identified unusual model behavior in MFSIM. Missile intercept altitudes did not occur as expected under stressful scenarios. One possible cause, radar dwell times under stress, was found not to be the source of the unusual behavior.

DoD KEY TECHNOLOGY AREAS: Conventional Weapons, Modeling and Simulation

KEYWORDS: MFSIM, PATRIOT, PAC-3, Tactical Ballistic Missile, TBM, Ballistic Missile Defense Oraganization, BMDO, Theater Missile Defense, TMD

MODELING SEA-BASED SUSTAINMENT OF MARINE EXPEDITIONARY UNIT (SPECIAL OPERATIONS CAPABLE) (MEU(SOC)) OPERATIONS ASHORE

Robert M. Hagan-Captain, United States Marine Corps
B.S., United States Naval Academy, 1989
Master of Science in Operations Research-September 1998
Advisor: David A. Schrady, Department of Operations Research
Second Reader: Ronald L. Brown, Department of Operations Research

The Marine Corps has embraced the concepts of Operational Maneuver From The Sea (OMFTS) and Ship-to-Objective Maneuver (STOM) as the next progression in the evolution of amphibious warfare. These related concepts envision harnessing emerging technologies to allow the projection of naval power ashore faster and from greater distances than in the past. Additionally, both concepts identify the ability to conduct sea-based logistics (SBL) as a key requirement for successful implementation. Sea-based logistics involves executing a wide range of logistical functions from a sea-base rather than from sites traditionally established ashore. Acknowledged enhancements are required to realize a complete SBL capability; however, the ability to provide some measure of sea-based sustainment exists today. This thesis models the sea-based sustainment of Marine Expeditionary Unit (Special Operations Capable) (MEU(SOC)) forces deployed from Amphibious Ready Group (ARG) ships. Missions are developed for analysis; each is coupled with an appropriate force package of personnel and equipment density. Sustainment requirements and available transportation capacities are then determined and compared for each mission. This comparison along with several excursions provides insight into the nature of sea-based sustainment feasibility. It also gauges potential limitations for sea-based sustainment.

DoD KEY TECHNOLOGY AREA: Other (Logistics)

KEYWORDS: Sustainment, Operational Maneuver From The Sea (OMFTS), Ship-to-Objective Maneuver (STOM), Sea-Based Logistics, Sea-Based Sustainment

PATIENT SATISFACTION:
A VISUAL ANALYSIS USING TRELLIS GRAPHICS

Tonya A. Hall-Lieutenant, United States Navy
B.S., West Virginia State College, 1991
M.S., Public Administration, 1994
Master of Science in Operations Research-September 1998
Advisor: Samuel E. Buttrey, Department of Operations Research
Second Reader: James Scaramozzino, Institute for Defense Education and Analysis

During times of peace, health care is one of the foremost quality of life issues to active duty members, their families and retirees. Patient satisfaction surveys are used to determine how patients perceive salient aspects of their medical care. There has been substantial anecdotal evidence to suggest that patients are unhappy with their care, but past analysis of the DoD Annual Surveys using simple frequencies of responses indicated that, overall, patients were satisfied. This thesis, using a powerful new technique called Trellis Graphics that allows more than three variables to be visualized simultaneously, has uncovered startling results that go beyond previous analysis, provide evidence to support the anecdotal claims, and show that overall satisfaction is not a reliable measurement for determining patient satisfaction. The seven factors defined by the National Committee on Quality Assurance are each individually, and together as a group, more reliable measures. The inability to choose a provider was clearly rated by every beneficiary group as the single greatest source of dissatisfaction. There are also differences in satisfaction between the sexes, and among the different groups. Active duty members, who are the primary customers of military treatment facilities, are the most dissatisfied, and women tend to be less happy than men.

DoD KEY TECHNOLOGY AREA: Other (Health Care, Statistics)

KEYWORDS: Patient Satisfaction, Military Health Care, Survey, Trellis Graphics

SURFACE SHIP SENSOR EMPLOYMENT AGAINST DIESEL SUBMARINES

Matthew Jordan Harrison-Lieutenant, United States Navy
B.S., United States Naval Academy, 1992
Master of Science in Operations Research-March 1998
Advisors: Wayne P. Hughes, Department of Operations Research
Don Brutzman, Undersea Warfare Academic Group
Second Reader: RADM John J. Ekelund Jr., USN (Ret)

This thesis provides tactical guidance for employment of surface ship sensors against torpedo-armed diesel submarines during littoral operations. Advantageous utilization of antisubmarine sensor systems in the littoral environment incorporates a blend of competent tactical experience and innovative thought processes and reflects environmental conditions, threat status, and mission priorities. Through extensive use of a modeling and simulation program, this thesis determines the preferred sensor employment configurations based on surface ship and submarine detection and counter-detection ranges and vulnerabilities to torpedo attack. Preference is based on a measure of effectiveness that minimizes the risk faced by surface ships from a diesel submarine threat, and provides tactical recommendations that are readily implementable as sensor employment policies.

DoD KEY TECHNOLOGY AREA: Electronic Warfare, Sensors, Surface/Under Surface Vehicles – Ships and Watercraft, Modeling and Simulation

KEYWORDS: Antisubmarine Tactics, Simulation, Sensor Employment, Antisubmarine Warfare

A SIMULATION ANALYSIS OF A SUPPRESSION OF ENEMY
AIR DEFENSE (SEAD) OPERATION

Nils K. Haugen-Lieutenant Commander, Royal Norwegian Navy
Master of Science in Operations Research-September 1998
Advisors: Donald P. Gaver, Department of Operations Research
Patricia A. Jacobs, Department of Operations Research
Second Reader: Arnold H. Buss, Department of Operations Research

Traditional SEAD operations rely on Wild Weasel aircraft equipped with Anti-Radiation missiles. This combination of real-time target acquisition capability with high precision weaponry has rendered surface-based radar systems vulnerable and ineffective. As a result, SEAD operations are decoupled from the slow and error-prone intelligence gathering and evaluation process proceeding conventional air-to-ground targeting. However, new technology allows modern air defense systems to combine increased mobility with a minimal use of radar, reducing the number of targets available to Wild Weasel aircraft. Consequently, more of the operational load is shifted over to conventional air-to-ground assets, making the SEAD operation more sensitive to the typical error and delay sources in the conventional targeting process.

This thesis uses a low-resolution simulation model to evaluate the impact of information delay on a SEAD operation. The results show that the effectiveness of a SEAD operation is sensitive to information delay, but not to the anticipated degree. Not surprisingly, the dominating variable for the success of the SEAD operation is the number of allocated SEAD aircraft. Next, but an order of magnitude less influential, is the delay in the SEAD intelligence cycle. Finally, the frequency of movement of the air defense units seems to play a minor role.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Suppression of Enemy Air Defense, Intelligence Cycle, Simulation

AN AGENT-BASED APPROACH TO ANALYZING
INFORMATION AND COORDINATION IN COMBAT

Richard B. Hencke-Lieutenant, United States Navy
B.S., California State Polytechnic University, Pomona, 1990
Master of Science in Systems Engineering-September 1998
Advisors: Donald P. Gaver, Department of Operations Research
Carl R. Jones, Information Systems Academic Group

The quality and quantity of information flows is a critical factor in the command and control of forces in battle. Many current simulations do not adequately show the interactive effects of information on the battlefield. Agent-based simulation is a promising technique that can provide insight into these effects.

The purpose of this thesis is to develop an agent-based simulation to analyze the relationship between information and command structure. (SinBaD) Simulation of Information in Battlefield Decisions is the agent-based simulation developed specifically for this thesis. Although SInBad is only an abstract model of combat, it is believed that this approach can provide much insight into the mechanisms that affect the effectiveness of information in battle.

Several combat scenarios are simulated using different control rules. These simulations suggest that there exists scenarios where information is essential to mission success and some cases where its role is less instrumental or even detrimental. Other insights generated from this research suggest that agent-based simulation may help define metrics useful in aiding decision-makers during the planning and execution of a large and complex campaign.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Agent-Based Simulation, Complexity Theory, Complex Adaptive Systems

FIRST TERM ATTRITION OF FUNDAMENTAL APPLIED SKILLS TRAINING (FAST) STUDENTS

Jeffrey W. Hickox-Lieutenant, United States Navy
B.S., United States Naval Academy, 1990
Master of Science in Operations Research-March 1998
Advisor: Samuel E. Buttrey, Department of Operations Research
Second Reader: Robert R. Read, Department of Operations Research

Fundamental Applied Skills Training (FAST) provides assistance to recruits with literacy skills deficiencies that could prevent them from successfully completing the recruit training cycle at Recruit Training Command, Great Lakes, Illinois. Short-term success of the program is known, but the long-term effects of this training are not known. In response to a Navy Training Requirements Review action item, this thesis examined the first term attrition of FAST students from Fiscal years 1993 and 1994 at yearly intervals. Analysis determined that FAST students have significantly lower attrition rate throughout the first term and a significantly higher reenlistment rate for a second term than sailors of similar abilities. Attrition of FAST students was similar to that of sailors of the upper mental group during the first term. The thesis includes a general overview of FAST research and a concise history of FAST development.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: FAST, Attrition, Naval Training, Navy Personnel, Skills

AN ANALYTICAL APPROACH TO OPTIMAL AIMING FOR THE ARMY TACTICAL MISSILE SYSTEM

Joseph S. Horab-Captain, United States Army
B.S., State University of New York at Buffalo, 1989
Master of Science in Operations Research-June 1998
Advisor: Alan R. Washburn, Department of Operations Research
Second Reader: LTC Charles H. Shaw, III, Department of Operations Research

After Desert Storm the Army Tactical Missile System's (ATACMS) range was increased from 165km to 300km. The increase in range was gained by reducing the total number of submunitions. To offset the loss of effectiveness, a global positioning system was added to the guidance unit to increase accuracy of the missile.

Further increases to the missile's effectiveness can be gained by optimizing the aimpoints at which the missile is fired. This can be accomplished by using an analytical function that predicts the probability of kill based on several parameters that are dependent on the type of target and missile. This function, through the use of a model such as the OpAimer model developed in this thesis, can then assure at least a locally optimal solution for the aimpoints. The parameters of the model include the target's location error, the accuracy of the missile and the shape of the distribution of a missile's bomblets about its center of impact.

Optimization methods such as the OpAimer model must become part of the current fire direction systems. Their inclusion will ensure that the ATACMS missile is used effectively and limited assets are not unnecessarily wasted.

DoD KEY TECHNOLOGY AREA: Conventional Weapons, Computing and Software

KEYWORDS: Army Tactical Missile System, ATACMS, Optimal Aiming

ANALYSES OF WEIGHT, BODY-FAT, AND PHYSICAL FITNESS TESTING STANDARDS, FOR ACTIVE DUTY MALE MARINES, WITH PROPOSED ALTERNATIVES

William J. Inserra-Major, United States Marine Corps
B.S., University of Arizona, 1986
Master of Science in Operations Research-September 1998
Advisors: Harold J. Larson, Department of Operations Research
LtCol Timothy L. Phillips, United States Marine Corps Representative
Second Reader: William K. Krebs, Department of Operations Research

The Marine Corps utilizes a three-event Physical Fitness Test (PFT) comprised of a 3-mile run, sit-ups, and pull-ups to assess the level of physical fitness of individual Marines. This thesis uses newly collected data from the Marine Corps to analyze the current weight and body-fat standards and compare them with proposed alternatives. The research investigates whether the current standards can be slightly relaxed without resulting in significant decreases in physical fitness performance. Additionally, this thesis investigates the validity of pull-ups as an indicator of muscular strength and endurance. The analysis compares the performance scores for two types of pull-ups (the dead-hang and kip methods) with other physical performance events which require upper body strength and muscular endurance. The thesis also presents proposed scoring alternatives for the pull-up event based on an analytical comparison of performance distributions for the run and sit-up events, in order to level the equality for all three PFT events. Additionally, a new 3-profile PFT alternative comprised of aerobic, muscular, and body composition profiles is presented as an improved measure of assessing the physical fitness of individual Marines.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Weight, Body-Fat, Physical Fitness Test, Pull-ups, Physical Fitness, Weight Control Program, Height-Weight Tables, Physical Performance, Muscular Strength, Muscular Endurance, Percent Body-Fat, Maximum Weight Limits, Percent Body-Fat Limits, Upper-Body Strength, Body Composition, Modified Pull-ups

MINIMIZING DRUG RELATED ATTRITION COSTS FOR INCOMING NAVAL RECRUITS

John J. Jacklich-Lieutenant, United States Navy
B.S., Mechanical Engineering, University of Washington, 1991
Master of Science in Operations Research-March 1998
Advisor: Samuel Buttrey, Department of Operations Research
Second Reader: Richard E. Rosenthal, Department of Operations Research

This thesis investigates alternative strategies for enforcing the Navy's zero-tolerance drug use policy among Navy recruits. Current policy relies mainly on the gas chromatography/mass spectrometry (GC/MS) urinalysis for recruits when they arrive at boot camp. GC/MS, a laboratory test, takes at least three days for confirmation. The cost of separating recruits who fail urinalysis or admit to drug use at boot camp is $2.7 million per year.

Key ideas investigated in the thesis are the administration of drug tests at Military Entrance Processing Stations (MEPS) on the day of shipping to boot camp, and the use of a new "non-instrumented" drug test (NIDT). The NIDT, though not as accurate as GC/MS, requires no laboratory equipment or expertise to administer and furnishes results immediately.

This thesis designs and recommends a new policy which includes NIDT testing for marijuana at the MEPS in addition to GC/MS at RTC. Through the use of detailed statistical, cost and sensitivity analyses, the thesis concludes that the Navy can save well over a $1 million per year by instituting this policy. These results have been reported to RADM Kevin Green, Commander of NTC, Great Lakes, who has announced his intention to adopt the new policy.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Recruit, Drug Testing, Attrition, Optimization, Policy, RTC Separation Costs

SIMULATING AN ISOCHRONAL SCHEDULED INSPECTION
SYSTEM FOR THE P-3 ORION

Jeffrey A. Jones-Lieutenant, United States Navy
B.S., Wichita State University, 1990
Master of Science in Operations Research-September 1998
Advisor: George W. Conner, Department of Operations Research
Second Reader: Arnold H. Buss, Department of Operations Research

The purpose of this thesis is to explore potential challenges facing the implementation of an Isochronal Scheduled Inspection System (ISIS) for the United States Navy's P-3 Orion. Implementation of ISIS, which is based solely upon calendar time, has been proposed to replace the present system of scheduled inspections that are based upon both calendar time and flight hours. The United States Customs Service and the Royal Netherlands Navy have successfully fielded the ISIS program and demonstrated that the concept works when implemented on a small scale. It is not known, however, how well the program might work when applied to a larger organization. This thesis obtains insights into potential troubles arising from implementation of the ISIS program by building and analyzing a simulation model. The model's output includes the number of times aircraft induction dates are rescheduled, and the number of days that scheduled aircraft induction dates are changed by. The analysis provides a measure with which to gauge the difficulty of implementing the ISIS program in the U.S. Navy.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Modeling and Simulation

KEYWORDS: Aviation, Scheduled Maintenance, Simulation, Java, Isochronal

TWO NEW NEAREST NEIGHBOR CLASSIFICATION RULES

Ciril Karo-Major, Australian Army
B.Sc., University College Australian Defence Force Academy,
University of New South Wales, 1989
Master of Science in Operations Research-September 1998
Advisor: Samuel E. Buttrey, Department of Operations Research
Second Reader: Harold J. Larson, Department of Operations Research

Nearest-Neighbor (NN) classification is a non-parametric discrimination and classification technique. In NN classification a test item is compared by some similarity measure of its multiple variables (usually a distance metric) with all the items in a training set. The class of the item to which it is most similar can be used as an indication of the class of the test item. In other words, the test item is assigned the class of its nearest neighbor. A key extension is the case when $k > 1$ nearest neighbors (k-NN) are examined with the classification usually being made based on a plurality. NN classification is used in many fields, including for example the field of Pattern Recognition. Applications include tasks like speech recognition by a computer, medical data interpretation and diagnosis, or the interpretation of remote sensing imagery from satellites. Military applications of the technique include any situation where automated recognition is required.

This thesis proposes two new NN rules that are intended to improve classification accuracy. The rules are tested against baseline classification methods in common use with a variety of data sets. One method shows improvement over the baseline methods in most of the data cases examined.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Sensors, Other (Statistics)

KEYWORDS: Nearest Neighbor Classification, Discrimination, Pattern Recognition

A COMPARISON OF AN ALTERNATIVE INVENTORY CONTROL CONCEPT WITH THE NAVY'S EXISTING WHOLESALE INVENTORY CONTROL PROCEDURES FOR REPAIRABLES

David R. Kless-Lieutenant Commander, United States Navy
B.S., United States Naval Academy, 1987
Master of Science in Operations Research-September 1998
Advisor: Kevin J. Maher, Department of Operations Research
Second Reader: Patricia A. Jacobs, Department of Operations Research

The Director of Planning and Operations Research Department, Naval Inventory Control Point (NAVICP) Code M041, requested a study to compare the performance of two sets of inventory control procedures for managing high-cost repairable items. One of these sets is embedded in the Navy's existing wholesale inventory control system. The procedures of this set characterize a periodic review process, which calculates four decision variables in order to manage Navy inventories. These variables represent how much to order, how much to repair, when to order, and when to repair. The other set of procedures are adapted from a commercial software package called Bandwidth Management developed by Stewart-Frazier Tools Inc. Two versions of these latter procedures are modeled in this thesis. These procedures characterize a periodic review process, which calculates three decision variables. These variables represent how much to deliver, how much to repair, and when to repair. This thesis uses simulation to model the two sets of procedures and to compare their performance with respect to three formal measures of effectiveness adopted by NAVICP: Supply Material Availability (SMA), Average Delay for a Delayed Requisition (ADDR), and Average Monthly Investment Level (AMIL). The comparison results of the thesis indicate that the existing Navy inventory procedures generate better performance in all three formal measures of effectiveness.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Navy Repairable Items, Inventory Models

A COMPARISON OF ANALYSIS IN DISTRIBUTED INTERACTIVE SIMULATION AND HIGH LEVEL ARCHITECTURE

Steven D. Knight-Captain, United States Army
B.S., United States Military Academy, 1988
Master of Science in Operations Research-June 1998
Advisor: Arnold H. Buss, Department of Operations Research
Second Reader: MAJ William S. Murphy, Jr., TRADOC Analysis Command-Monterey

As the Department of Defense (DoD) continually relies more on Modeling and Simulation (M&S) for testing, analyzing, and training, issues of interoperability have become one of the most important concerns. As such, DoD adopted the Distributed Interactive Simulation (DIS) protocol in 1991. Although successful in many aspects, DIS is limited by available information from models, memory and network requirements, and analytical tools available. Therefore, in 1996 the Defense Modeling and Simulation Office (DMSO) released the High Level Architecture (HLA), an object-oriented approach to interoperability.

This thesis compares these different approaches to analysis to determine functionality in terms of gathering, processing, and reporting on analytical questions in both environments. To compare DIS and HLA analysis, three simulation runs were conducted: Janus vs. Janus in DIS, HLA without an Analysis Federate, and HLA with an Analysis Federate. The Analysis Federate is an HLA-compliant software package that gathers and processes information for analysis requirements. The results of the three simulation runs and subsequent analysis demonstrated the techniques and approaches for each infrastructure. The resulting comparison between them show HLA with the Analysis Federate is the easiest and most functional tool.

The Analysis Federate fills an analysis void currently in HLA and by implementing it with the study question model tree methodology, an analyst will be more effective and be able to provide real-time feedback.

ANALYSIS OF NAVY DELAYED ENTRY PROGRAM AND RECRUIT TRAINING CENTER ATTRITION

Bryant W. Knox-Lieutenant, United States Navy
B.A., Davidson College, 1985
M.S., Boston University, 1998
Master of Science in Operations Research-June 1998
Advisor: Samuel E. Buttrey, Department of Operations Research

Attrition from the Navy's Delayed Entry Program (DEP) and attrition from Bootcamp are costly phenomena. The Commander of Naval Recruiting (CNRC) and Center for Naval Analysis (CNA) have periodically modeled both DEP and Bootcamp attrition with logistic regression. This thesis analyzes current data provided by CNRC and CNA. Both DEP and Bootcamp attrition are modeled using logistic regression and tree-structured classification. For DEP, the logistic model indicates that individuals who accept incentives prior to enlistment (i.e., Navy College Fund or Enlisted Bonus Program) and individuals who change enlistment programs (while in DEP) have a significantly lower propensity to attrite from DEP than others. The DEP tree model indicates that an individual with a low Armed Forces Qualification Test (AEQT) score, no high school diploma and a long scheduled DEP duration has a 97% probability of attriting. For Bootcamp, the logistic model indicates that individuals who use tobacco products, individuals who do not exercise, and individuals that have criminal waivers have a significantly higher propensity to attrite than others. The Bootcamp tree model shows that smokers and individuals with low AFQT scores have higher propensities to attrite than others. The models are tested using random partitions and this analysis shows that all of the models predict poorly at the individual level, despite strong statistical significance.

OPTIMIZING SELECTION OF TOMAHAWK CRUISE MISSILES

Scott D. Kuykendall-Lieutenant, United States Navy
B.S., United States Naval Academy, 1992
Master of Science in Operations Research-March, 1998
Advisor Richard E. Rosenthal, Department of Operations Research
Second Reader: George W. Conner, Department of Operations Research

The Tomahawk Land Attack Cruise Missile (TLAM), launched from surface ships and submarines, has become the weapon of choice for the United States in many situations. In an era of high-precision, fast-delivery weapons, the method currently used for assigning TLAM engagements is out of step with the development of the weapons themselves. Missile assignment today is manual, with the potential consequences of inefficient missile-to-mission matching and unnecessary delay.

This thesis develops a new optimizing approach to missile-to-mission matching, using integer programming. In a matter of seconds for a single ship or a matter of minutes for a battle group, the optimization model determines which missile to select for each tasking order and provides back-up assignments if requested. The objective of the model is to ensure the correct weapon is applied against each target while maximizing the potential of the firing unit(s) to perform future taskings.

The new missile-to-mission matching model is better than current methods and performs robustly in extensive sensitivity analyses. The optimization model is currently being considered for shipboard implementation by the Naval Surface

Warfare Center. At the very least, the model can be used to independently assess the performance of any new missile-to-mission matching decision support considered by the Navy.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Conventional Weapons

KEYWORDS: Tomahawk Land Attack Cruise Missiles (TLAM), Vertical Launch System (VLS), Missile Selection, Missile-to-Mission Matching (M3)

HUMAN FACTORS ANALYSIS OF UNITED STATES NAVY AFLOAT MISHAPS

Rex D. Lacy-Lieutenant Commander, United States Navy
B.S., Georgia Institute of Technology, 1982
M.S., Central Michigan University, 1988
Master of Science in Operations Research-September 1998
Advisor: Samuel E. Buttrey, Department of Operations Research
Second Reader: CDR John K. Schmidt, School of Aviation Safety

The effects of maritime mishaps, which include loss of life as well as environmental and economic considerations, are significant. It has been estimated that over 80 percent of maritime accidents are at least partially attributable to human error. Human error has been extensively studied in a number of fields, particularly aviation. The present research involves application of the Human Factors Accident Classification System (HFACS), developed by the Naval Safety Center, to human error causal factors identified in selected investigation reports of significant mishaps occurring on U.S. Navy afloat and diving units from 1992 to 1996. An evaluation of the reliability of the classification system was performed by measuring the level of agreement between two independent raters' application of the system to mishap analysis. Descriptive statistics and categorical data analysis were performed and meaningful insights were revealed regarding the types of human error that were associated with afloat naval mishaps. Comments and recommendations regarding implementation of the classification system for use in maritime accident analysis are provided.

DoD KEY TECHNOLOGY AREA: Other (Accident Analysis)

KEYWORDS: Maritime Mishaps, Accident Analysis, Human Factors, Human Error

ARMY SPECIAL OPERATIONS LOGISTICS PLANNING AID

Timothy S. Lanquist-Lieutenant Junior Grade, United States Navy
B.S., United States Naval Academy, 1995
Master of Science in Operations Research-September 1998
Advisor: LTC Charles H. Shaw, III, Department of Operations Research
Second Reader: David A. Schrady, Department of Operations Research

Given the clandestine nature of Special Operations Forces' (SOF) missions and the inability to adequately predict possible contingency scenarios, it is imperative that SOF logistics support be flexible and responsive. Currently, SOF logistics support is inequitable across Service lines, of limited joint flexibility, and has no single point of contact for logistics planning, coordination, and command and control resulting in inconsistent support for SOF operations. The possible implementation of a Joint Special Operations Logistics Command (JSOLOGCOM) has the potential to greatly improve support to SOF using all existing resources and is consistent with logistics concepts espoused in Joint Vision 2010 and SOF Vision 2020. The first step in evaluating the JSOLOGCOM concept for feasibility is a determination of logistical requirements for SOF units' missions. This thesis provides SOF logistics planners with generic planning factors for all classes of supply and specific planning factors for Class V, Ammunition, and Class VIII, Medical. It outlines a methodology that can be used to determine mission specific planning factors for any class of supply as well as field services. This thesis has also provided SOF logistics planners with a computer based, user-friendly, and flexible logistics planning aid that can be used to create more accurate logistics estimates than they have been able to in the past.

DoD KEY TECHNOLOGY AREA: Other (Logistics)

KEYWORDS: Logistics, Special Operations Forces, Army, Planning Factors

COMPARISON OF PROFICIENCY OBJECTIVES, PERFORMANCE OBJECTIVES, AND SUCCESS AT FOLLOW-ON TRAINING

Johnna M. Marchant-Lieutenant, Unites States Navy
B.S., Portland State University, 1986
Master of Science in Operations Research-September 1998
Advisor: Samuel E. Buttrey, Department of Operations Research
Second Reader: John Thain, Department of Evaluation and Research, Defense Language Institute

The Defense Language Institute Foreign Language Center (DLIFLC) trains students in over 21 foreign languages for the Department of Defense (DoD). The National Security Agency (NSA) and Defense Intelligence Agency (DIA) are responsible for setting the training objectives for students entering professional fields in intelligence.

In the past, general proficiency in listening, reading, and speaking skills has been the focus of language learning and testing in the DoD. Certain minimum scores on the Defense Language Proficiency Test (DLPT) are required for certain training and operational positions within the DoD. DoD has not established applicable performance objective scores for training and operational positions. Individual service commanders at DLIFLC may exercise some discretion in borderline cases where general minimum DLPT requirements have not been met. They may take into account performance objective scores and grant waivers for attending Goodfellow Air Force Base (GAFB) follow-on training.

The purpose of this study is to determine how the performance objective scores relate to success on the DLPT and how the combination of DLPT and performance objective tests might possibly relate to success on follow-on training at GAFB. Success at GAFB is defined by on-time graduation, number of required special-assistance hours, and performance on "block" tests.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: DLPT, Performance Objective

AN ANALYSIS OF THE IMPACT OF MILITARY EXPORT OFFSETS ON THE UNITED STATES INDUSTRIAL BASE

David G. McCord-Captain, United States Marine Corps
B.S., United States Naval Academy, 1989
Master of Science in Management-September 1998
Advisors: Thomas H. Hoivik, Department of Operations Research
Sandra M. Desbrow, Department of Systems Management

The purpose of this thesis is to determine what effect the growth of offsets, as a condition of sale of military articles, has had on the U.S. defense industrial base. These effects are measured by assessing how this trade practice has impacted the employment, trade, and competitiveness of the U.S. defense industry. Additionally, the present U.S. Government policy towards offsets is explained. Analytical data taken from both Office of Management and Budget and Department of Commerce reports are presented and analyzed. Interviews with large and small- to medium-sized business spokesmen, in addition to Department of Commerce experts, are presented to augment the quantitative results. Different levels of U.S. Government oversight are explained as well as their advantages and disadvantages. The macroeconomic effects of offsets on the U.S. defense industry are inconclusive. However, offsets do seem to impact the U.S. defense industry adversely at the subcontractor level when specific industrial sectors are analyzed. Large defense contractors view offsets as a necessary marketing tool in order to maintain global competition. Most small- to medium-sized contractors do not support the use of offsets, claiming that they export jobs and work orders overseas, eroding the defense industrial base at the subcontractor level.

ANALYSIS OF PREDICTIVE FACTORS FOR FULLY MISSION CAPABLE RATES OF DEPLOYED AIRCRAFT

Patricia B. Moore-Lieutenant Commander, United States Navy
B.A., State University of New York, Binghamton, 1982
Master of Science in Operations Research-September 1998
Advisor: Samuel E. Buttrey, Department of Operations Research
Second Reader: Lyn R. Whitaker, Department of Operations Research

As the U.S. military reduces its forces, the ability to maintain an acceptable level of readiness is of concern to the U.S. Navy. Both personnel and equipment readiness and the ability to predict them have been the focus of much attention. Fully Mission Capable (FMC) rates measure the percentage of time that aircraft are fully able to meet mission requirements. FMC rates have been determined to be the best single measure of equipment condition, providing an indication of aircraft readiness. This thesis evaluates the capabilities of logistic regression and regression trees in predicting aircraft readiness for a specific carrier deployment or aircraft type/model/series (TMS). The data are taken from observations of squadrons by aircraft TMS by month from 1981 through 1997. Empirical results indicate that logistic regression and regression trees provide forecasting results with standard errors of prediction better than taking the mean and standard deviation of the historical data.

BATTLE GROUP ORDNANCE AND FUEL LOGISTIC TASK MEASURES OF PEFORMANCE FOR THE UNIVERSAL NAVAL TASK LIST

Gary L. Morris-Lieutenant, United States Navy
B.S., United States Naval Academy, 1992
Master of Science in Operations Research-September 1998
Advisors: George Conner, Department of Operations Research
Kevin J. Maher, Department of Operations Research
Second Reader: Alan R. Washburn, Department of Operations Research

A set of well-defined and quantifiably justified Measures of Performance (MOPs) is required for the armament and fuel tasks of a Carrier Battle Group (CVBG) as described in the Universal Naval Task List (UNTL). These MOPs are incorporated in the CVBG's training plan and provide the BGCDR a method to evaluate the CVBG's level of ability to perform the necessary tasks. This thesis proposes 37 MOPs and the methodology to subjectively evaluate the MOPs to determine which ones are well defined, and objectively evaluate them to determine how well they collectively measure task performance. The proposed MOPs are derived from the task descriptions and objectives found in the UNTL. They are subjectively scrutinized using the twelve criteria required by the UNTL and objectively evaluated using correlation analysis. A simulation is developed for each task to provide the data for the objective analysis. The results indicate that 23 of the 37 proposed MOP's meet the required criteria of being well defined and useful in measuring task performance. Based upon the developed methodology, it is recommended that the Naval Doctrine Command consider the 23 MOPs for inclusion into its revised UNTL.

A TASK ANALYSIS OF UNDERWAY REPLENISHMENT FOR VIRTUAL ENVIRONMENT SHIP-HANDLING SIMULATOR SCENARIO DEVELOPMENT

Steven D. Norris-Lieutenant, United States Navy
B.S., Norwich University, 1992
Master of Science in Computer Science-September 1998
Advisors: Rudolph P. Darken, Department of Computer Science
John S. Falby, Department of Computer Science
Second Reader: Dylan Schmorrow, Department of Operations Research

While developing a Virtual Reality (VR) Ship-handling simulator for the Surface Warfare Officer School (SWOS) in Newport, RI, researchers at the Naval Air Warfare Center Training Systems Division (NAWCTSD) in Orlando, FL discovered a need for a task analysis of a Conning Officer during an Underway Replenishment (UNREP). The purpose of this task analysis was to document the tasks the Conning Officer performs and cues used to accomplish these tasks. The task analysis would ensure that the correct tasks and cues would be modeled in the VR UNREP scenario.

The approach taken was to survey cognitive task analysis models to find a notation that would document the tasks performed by a bridge team during an UNREP. The Goals, Operators, Methods, Selection Rules (GOMS) model was selected. A GOMS-like model was used to represent the sequential aspects of the UNREP task, while a table was developed to capture the parallelism of the tasks. The UNREP task analysis was then reviewed by qualified Surface Warfare Officers to validate its accuracy.

The result of this effort was a validated task analysis model of a Conning Officer during an UNREP. This model was provided to NAWCTSD in support of their future efforts in the development of a VR UNREP Ship-handling simulator scenario.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Human Systems Interface, Manpower, Personnel and Training, Modeling and Simulation

KEYWORDS: Ship-handling, Virtual Reality, Task Analysis, Virtual Environment, Surface Warfare, Computer Simulation, Underway Replenishment, Computer Graphics

CLASSIFYING PUBLIC SWITCH TELEPHONE NETWORK (PSTN) SWITCHING STATIONS: A NATIONAL SECURITY AGENCY APPLICATION

Allen S. Olson-Major, United States Marine Corps
B.S., University of Minnesota, 1982
Master of Science in Operations Research-September 1998
Advisors: R. Kevin Wood, Department of Operations Research
Norman D. Curet, National Security Agency
Second Reader: Gerald G. Brown, Department of Operations Research

The U.S. National Security Agency wishes to predict the routing of messages over various communications networks. Before routing predictions can be made in a public switch telephone network (PSTN), the hierarchical level of the network's switching stations must be known. This thesis develops an integer linear programming model for accomplishing this classification. In this model, a PSTN is represented as a graph in which switching stations are nodes and the logical connections between the switching stations are arcs. Algebraic constraints represent the engineering standards common to PSTNs. The model also incorporates probabilistic inferences about the class of switching stations to improve classification accuracy for networks not following typical PSTN structural practices. Preprocessing routines that analyze the network's topology and employ various heuristics to reduce the size of the problem are evaluated. The sample PSTNs are solved using IBM's Optimization Subroutine Library solver on a 166 MHz desktop model is implemented in Generic Algebraic Modeling System Development Corporation's GAMS and personal computer. Accurate classification solutions are obtained in under two seconds for actual PSTNs, while extremely large notional networks of over 300 nodes and 900 arcs are solved in under two minutes.

ANALYZING SENSOR-SHOOTER LINKS THROUGH SIMULATION

Keith E. Olson-Captain, United States Army
B.S., United States Military Academy, 1988
Master of Science in Operations Research-June 1998
Advisor: LTC Charles H. Shaw, III, Department of Operations Research
Second Reader: Samuel H. Parry, Department of Operations Research

Today's military is changing. We are changing the size and structure of our forces, reevaluating our missions, and looking at military applications of new and emerging technologies. Simulation will play a key role in aiding decision-makers during these changes. This thesis demonstrates the development and use of simple, single-purpose simulation models. These models answer specific questions and can be created quickly with readily available tools. The simulation developed in this thesis is designed to serve as a basis for further studies involving the Longbow Apache. This simulation is a stochastic, process-oriented, event-step model.

To demonstrate the use of this model, a comparative analysis was performed to evaluate two field artillery "call-for-fire" procedures. Is a proposed call-for-fire procedure based on new digital technologies superior to the current process? The experiment incorporated a pre/post-process design resulting in paired observations of the artillery's effectiveness before and after incorporation of the new technology.

Results indicate the proposed procedure is superior to the current procedure. Sensitivity analysis was also performed on two input parameters as a three-by-three factorial experiment. This analysis concluded the previous results were sensitive to the specific parameter values chosen. Recommendations are made for model improvement and topics for future study.

ALLOCATING FLIGHT HOURS TO ARMY HELICOPTERS

Bradley W. Pippin-Captain, United States Army
B.S., United States Military Academy, 1988
Master of Science in Operations Research-June 1998
Advisor: Robert F. Dell, Department of Operations Research
Second Reader: Thomas Halwachs, Department of Operations Research

Army helicopter battalions, consisting of 24 helicopters valued from $206.4 million (1311-60 Blackhawk battalion) to $432 million (ALH-64 Apache battalion), allocate flight hours to helicopters using manual techniques that have caused an unnecessary decrease in battalion deployability. This thesis models the battalion's flight hour allocation problem using optimization; it develops both a mixed integer linear program and a quadratic program. The 2nd Battalion, 4th Aviation Regiment of 4th Mechanized Division, currently uses a spreadsheet implementation of the quadratic program developed by the author called QFHAM (Quadratic Flight Hour Allocation Model), that is available to other battalions for use with existing software and computer resources. The mixed integer linear program, called FHAM (Flight Hour Allocation Model) more appropriately models the problem, but requires additional software. This thesis validates the two models using actual flight hour data from a UH-60 battalion under both typical training and contingency scenarios. The models provide a monthly flight hour allocation for the battalion's aircraft that results in a steady-state sequencing of aircraft into phase maintenance, thus eliminating phase maintenance backlog and providing a fixed number of aircraft available for deployment. This thesis also addresses the negative impact of current helicopter battalion readiness measures on deployment and offers alternatives.

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Helicopter, Flight Hour Allocation, Phase Maintenance

ANALYSIS OF MID-GRADE NAVAL AVIATOR RETENTION
Scott H. Poindexter-Major, United States Marine Corps
B.S., United States Naval Academy, 1984
Master of Science in Operations Research-September 1998
Advisors: William Krebs, Department of Operations Research
Samuel Buttrey, Department of Operations Research
Second Reader: CDR John K. Schmidt, School of Aviation Safety

Attrition of aviators is of major concern to the Navy because of the costs and numbers involved. The Navy currently forecasts aviator retention and attrition by extrapolating historical trends. This thesis recommends that the Navy replace the current method with two alternative statistical techniques: *logistic regression* and *classification trees*. They are recommended for two reasons. First, the proposed techniques make significantly more accurate forecasts of aviator retention than the current method. Second, the proposed techniques, unlike the current method, can identify the significant variables affecting aviator retention. Use of the proposed techniques can therefore lead to the formulation of better aviator retention policies by the Navy. These arguments are demonstrated with a case study of an existing retention database. The variables identified as most significant for aviator retention in this analysis were the geographic location of an aviator's duty station, assignment to non-flying billets, and grade. Policy implications of these findings are discussed.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Retention, Employee Turnover, Naval Aviation, Manpower, Logistic Regression, Classification Trees

A FORCED ENTRY PLANNING MODULE FOR AMPHIBIOUS AIR ASSAULTS FOR THE JOINT WARFARE ANALYSIS EXPERIMENTAL PROTOTYPE
George D. Pointon-Major, United States Marine Corps
B.S., United States Naval Academy, 1986
Master of Science in Operations Research-March 1998
Advisors: Samuel H. Parry, Department of Operations Research
Mark Youngren, Department of Operations Research

The most difficult challenge in modeling and simulating modern warfare is the attempt to address every possible scenario, operating plan, and tactic. One such model is the Joint Warfare Analysis Experimental Prototype (JWAEP) being developed at the Naval Postgraduate School. A scenario in which JWAEP needs further development is littoral warfare, which for the Marine Corps represents amphibious assault operations. An aspect of this type of warfare is referred to as "forced entry" when friendly ports are not available in the region of interest. Forced entry occurs by air, sea, or a combination of air and sea. Although these missions are very complex, mission planning is similar for each mode of transport. This thesis introduces the Forced Entry Planning Module (FEPM), a tactical decision planning aid, and offers a test of the conceptual amphibious air assault portion of FEPM using the most current United States Marine Corps amphibious air assault doctrine.

The concept was tested by constructing a stand-alone model, using deterministic combat attrition, to evaluate three potential methods for choosing a route to an amphibious air assault objective under uncertainty. The results indicated that each of the proposed methods predicted mission outcome under uncertainty with varying degrees of success. This limited testing has validated the concept of FEPM and the proposed methods. However, further refinement and testing is required before a final determination of which method is "best" for evaluating routes for forced entry missions is made.

AN OBJECT-ORIENTED DISCRETE-EVENT SIMULATION OF LOGISTICS (MODELING FOCUSED LOGISTICS)

John L. Ruck-Lieutenant Commander, United States Navy
B.S.E., Tulane University, 1982
M.S., Central Michigan University, 1995
Master of Science in Operations Research-September 1998
Advisor: Arnold H. Buss, Department of Operations Research
Second Reader: Gordon Bradley, Department of Operations Research

Joint Vision 2010 puts forth four operational concepts describing how U.S. forces will conduct combat in the future. One of these concepts is Focused Logistics, which Joint Vision 2010 defines as "the precise application of logistics." In order to study the effects of Focused Logistics, a flexible method of simulating possible logistics systems is needed. The Flexible Experimental Logistics Simulator (FLEXLOGS) is an object-oriented, discrete-event simulation that is designed to be used to evaluate proposed future logistics strategies. First, the author develops a model capable of simulating any proposed logistics scheme with minimal modification to the software. Second, the thesis discusses the design and use of the model.

Finally, the model is used to explore the shape of curves defined by the probability of combat victory verses "logistical footprint size" and "premium transportation availability." The model implements the draft Logistical Conceptual Object Model being developed as part of the *Focused Logistics Study* by the Office of the Secretary of Defense, Program Analysis and Evaluation, Simulation Analysis Center.

A BENCHMARK USABILITY STUDY OF THE TACTICAL DECISION-MAKING UNDER STRESS DECISION SUPPORT SYSTEM

Dylan D. Schmorrow-Lieutenant, United States Navy
B.S., Western Michigan University, 1989
Ph.D., Western Michigan University, 1993
Master of Science in Modeling, Virtual Environments, and Simulation-September 1998
Advisor: Rudolph Darken, Department of Computer Science
Second Reader: George Conner, Department of Operations Research

This study evaluates the usability of a U.S. Navy Decision Support System (DSS). The DSS was developed to enhance the performance of tactical decision-makers within a Navy Combat Information Center. The goals of this study were to test the DSS against usability criteria and objectives to track future redesign efforts and system improvements. The purpose of this analysis was to: (1) assess the system's usability, (2) identify problems areas in the graphical user interface, (3) report trends in user feedback, and (4) provide recommendations addressing major usability issues encountered by participants. The study tested whether the DSS met the usability objectives of: (a) 90% successful task completion, (b) ease-of-use ratings of somewhat easy or better, and (c) satisfaction ratings of somewhat satisfied or better. The DSS did not meet these usability objectives for task completion or ease-or-use; however, the DSS did meet the usability objective for user satisfaction. All participants reported that they enjoyed working with the DSS and believed that it would be a significant step forward in information management. Based on the usability data gathered in the study, recommendations are provided to address the usability issues.

DoD KEY TECHNOLOGY AREA: Human Systems Interface

KEYWORDS: Usability, Human Factors, Human Computer Interaction, Synthetic Environments, Decision Support

DYNAMIC PLATFORM INDEPENDENT META-ALGORITHMS FOR GRAPH-PARTITIONING

Victor Scott Schwartz-Lieutenant, United States Navy
B.S., University of Nebraska, 1992
Master of Science in Operations Research, September 1998
Advisor: Gordon H. Bradley, Department of Operations Research
Second Reader: R. Kevin Wood, Department of Operations Research

A dynamic platform-independent solver is developed for use with network and graph algorithms of operations research. This solver allows analysts to solve a large variety of problems without writing code. Algorithms from a library can be integrated into a meta-algorithm which also provides easy monitoring of solution progress.

The solver, DORS, is demonstrated by heuristically solving a graphpartitioning problem to minimize the number of nodes adjacent to other segments of the partition. The model arises from a network-upgrade project faced by the Defense Information Systems Agency (DISA), a problem with over 200 nodes and 1400 arcs. Solutions are provided on a 266 MHz Pentium H PC using Windows NT 4.0. Eight variants of the problem are solved involving modification to the objective function, constraints on the size of partition segments, and on the number of those segments.

DORS (and the meta-algorithm it implements) appears to find a good solution for one of the two problem formulations for DISA, but has difficulty solving the other Because the solver allows new algorithms to be easily added to create more powerful meta-algorithms. DORS should provide a good solution approach for both problem formulations given a more versatile library of algorithms.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation

KEYWORDS: Graph Partitioning, Java

COST ANALYSIS OF INTER-DEPOT TRANSPORTATION OPTIONS FOR U.S. NAVY EAST COAST AIR-LAUNCHED MISSILES

Charles L. Sellers-Lieutenant, United States Navy
B.S., Virginia Polytechnic Institute and State University, 1990
Master of Science in Operations Research-September 1998
Advisor: David G. Brown, Department of Systems Management
Second Reader: Kevin J. Maher, Department of Operations Research

Since the disintegration of the Warsaw Pact and the Soviet Union, the Department of Navy has had to learn how to meet its commitments with an ever-decreasing budget. One Navy community addressing this downsizing is the east coast ordnance community. Because of restructuring and the closure of Weapon Station Charleston, South Carolina, the remaining east coast weapon stations are handling the same amount of ordnance with fewer personnel. As a result of the restructuring, the aircraft carriers, ordnance ships, and large deck amphibious ships conduct ordnance transfers at Naval Weapon Station (NWS) Earle, New Jersey. These ships all carry air-launched missiles that have to be maintained at Naval Weapons Station Yorktown. This thesis develops cost equations associated with several different methods of transportation (commercial and Department of Defense). These equations are being used to generate cost curves for each of four types of missiles being transported between NWS Earle and NWS Yorktown. The curves are analyzed, and decision policies are determined which ensure the most cost-effective method of transportation is being used to transport the missiles.

DEVELOPMENT OF A TEST MECHANISM FOR ANALYZING FORCE ATTRITION METHODOLOGIES WITHIN AGGREGATED COMBAT SIMULATIONS

Michael L. Shenk-Captain, United States Army
B.S., Clarion University of Pennsylvania, 1988
Master of Science in Applied Mathematics-June 1998
Advisors: Bard K. Mansager, Department of Mathematics
James G. Taylor, Department of Operations Research

For aggregated combat simulation models, the methods for calculating force attrition must be based upon sound mathematical formulations and parameter estimations. With an inherent lack of representative combat data for modern warfare scenarios, one effective method for determining the required parameter estimates is to thoroughly analyze the output from a stochastically based high-resolution combat model. It is this development of attrition parameters process, which so profoundly influences the validity of aggregated simulations, that lacks any comprehensive documentation or mathematical justification within the modeling community. By examining the development and validity of these processes for parameter estimation, valid attrition calibration formulae can be determined and used within force attrition algorithms in order to more precisely and justifiably model aggregated combat operations. The establishment of a user-friendly test bed for examining this attrition rate development process will play a major role in solidifying the understanding, implementation, and validation of current and future process techniques.

OPTIMAL RECRUITING STRATEGY TO MINIMIZE U.S. NAVY DELAYED ENTRY PROGRAM (DEP) ATTRITION

Paul G. Simpson-Lieutenant, United States Navy
B.S., United States Naval Academy, 1988
Master of Science in Operations Research-December 1997
Advisor: Richard E. Rosenthal, Department of Operations Research
Second Reader: Harold Larson, Department of Operations Research

This thesis develops an optimization-based model to assist the Navy Recruiting Command in placing nuclear power field recruits in the Delayed Entry Program (DEP). After signing enlistment contracts, individuals are enrolled in the DEP prior to entering recruit training. During DEP, some individuals may renege on their contracts, thus becoming DEP losses. Although DEP is costly, it is a necessary and important inventory management tool since it provides a pool of recruits to meet future accession goals.

The DEP placement problem is formulated as a nonlinear program that minimizes relative recruiting costs weighted with respect to the desired recruit category. The lowest recruiting costs are assigned to recruits in DEP lengths that ensure the lowest probability of becoming a DEP loss. Increased costs are assigned to direct shippers. A large penalty cost is assigned to monthly accession deficits. Integral to the model are estimates of DEP loss probability for the various combinations of recruit categories and DEP lengths.

This research concludes that the annual new contract objective (NCO) does not support the successful attainment of the accession goal. Furthermore, a NCO increase of 20% is required to achieve the accession goal with a 95% confidence level. Finally, the thesis addresses the accession goal confidence levels associated with incremental increases of the NCO.

COMPANY TEAM SURVIVABILITY AT THE U.S. ARMY NATIONAL TRAINING CENTER

Steven A. Stoddard-Captain, United States Army
B.S., United States Military Academy, 1988
Master of Science in Operations Research-June 1998
Advisor: Harold J. Larson, Department of Operations Research
Second Reader: Samuel H. Parry, Department of Operations Research

This research answers the following questions about training exercises at the Army's National Training Center (NTC) at Fort Irwin, California: "Which company team was the most survivable in the task force?" and "What did that company team do differently to become the most survivable?" The research examines data collected over four month-long brigade training exercises at the NTC, including analysis of 88 company team battles. The measure of effectiveness (MOE) is the average system survival time for each company team for each battle. The company team that achieves the highest MOE score for a battle is considered the most survivable company team. The MOE is scaled for comparisons over the course of many battles. The MOE is then used as the dependent variable for a series of separate analyses of the data, which answer the second question. These analyses use a collection of 20 independent variables and six research questions to differentiate between more and less survivable company teams. The conclusions are that company teams whose leadership survives longer, who have a higher proportion of tanks, and who perform security operations better are more survivable. The research further recommends that the NTC's data collection efforts be automated and standardized among the collection teams.

OPERATIONAL ANALYSIS OF THE SUSTAINABILITY OF A MOBILE MILITARY PLATFORM

James G. Stoneman-Lieutenant, United States Navy
B.S., United States Naval Academy, 1990
Master of Science in Operations Research-September 1998
Advisors: Donald P. Gaver, Department of Operations Research
Patricia A. Jacobs, Department of Operations Research
Second Reader: Ronald L. Brown, Department of Operations Research

This thesis illustrates the use of simulation techniques to evaluate the satisfaction of suitability requirements for a mobile platform carrying payload (for example, an Unmanned Aerial Vehicle with sensors) on a military mission (surveillance or reconnaissance). The Institute for Defense Analyses, in support of Director, Operational Test & Evaluation (DOT&E), recently developed a simulation to assist in the analysis of the Predator Unmanned Aerial Vehicle. That simulation has been extended to make it more applicable to a variety of platforms, and the extended simulation has been incorporated into the Military Aircraft Sustainability Simulation (MASS). The primary output from the simulation is an estimate of Effective Time On Station (ETOS), as that depends on platform subsystem reliability and the maintenance resources allocated. ETOS is the long-run percentage of time that the region under surveillance is being covered by at least one operating platform. An analytical model for a single platform also has been developed to augment and assist in verifying the MASS. This thesis shows that MASS can be an invaluable tool for evaluating a platform's suitability for a mission. The simulation can assist during the acquisition process, when the government must decide whether to buy a platform, and the simulation can assist in determining the most effective way to deploy such platforms once they are in use.

JOB SATISFACTION AMONG UNITED STATES NAVY AND MARINE CORPS AVIATION OFFICERS–A STUDY OF THE IMPACT ON CAREER RETENTION

Daniel J. Sullivan-Major, United States Marine Corps
B.S.I.E., Georgia Institute of Technology, 1985
Master of Science in Operations Research-September 1998
Advisors: William Krebs, Department of Operations Research
Samuel E. Buttrey, Department of Operations Research
Second Reader: CDR John K. Schmidt, School of Aviation Safety

United States Naval Aviation Officer retention has been identified by senior-level personnel managers as one of the largest challenges faced by the services in recent years. In robust economic times all branches of the armed forces face the challenge of retaining sufficient highly-trained volunteers. The aviation community is disproportionately affected due to the long lead time associated with aviation officer training
and the potential for long-term lucrative civilian job opportunities compared with existing military pay and benefits. This study documents the development of a retention survey aimed to quantify Naval aviation officer attitudes towards job satisfaction and turnover intent. Previous research has indicated that measurements of job satisfaction are the most reliable predictor of one's intent to remain with an existing employer. To best understand this relationship, CART and logistic regression models are proposed to predict Naval aviation officer retention. These models were developed using a principal components analysis of survey data elements. Work satisfaction and age were analyzed in terms of their impact as moderators of the relationship between job satisfaction and retention. Work satisfaction factors were found to be significant in models that predicted turnover intent half again better than if one was to merely provide a sample estimate.

HELICOPTER TERRAIN NAVIGATION TRAINING USING A WIDE FIELD OF VIEW DESKTOP VIRTUAL ENVIRONMENT

Joseph A. Sullivan-Lieutenant Commander, United States Navy
B.S., Catholic University of America, 1986
Master of Science in Computer Science-September 1998
Advisor: Rudolph P. Darken, Department of Computer Science
Second Reader: Dylan Schmorrow, Department of Operations Research

Helicopter terrain navigation is a unique task; training for this task presents unique challenges. Current training methods rely on dated technology and inadequately prepare pilots for real-world missions. Improved training specifically tailored to address the unique needs of the helicopter community that capitalizes on recent improvements in desktop virtual environment (VE) technology could substantially improve the training process and reduce training costs.

Based on the input of subject matter experts in current helicopter terrain navigation training techniques and VE technology, such a system was developed and tested on student pilots performing real-world tasks. A desktop VE that presented a simple to control and learn, interactive fly-though of a terrain model was used to augment conventional training at Helicopter Antisubmarine Squadron TEN (HS-10).

Results indicate that flight time for students that received VE training was more productive than for students that received conventional training. This work justifies the next logical step: fielding a system on a long-term basis as a squad-

ron asset. This system would provide improved training for the helicopter community and an invaluable source of research data for the Naval Postgraduate School.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (Training)

KEYWORDS: Virtual Environments, Terrain Association, Navigation, Training, Mission Rehearsal, Helicopters

A MONTHLY SORTIE SCHEDULING MODEL FOR IMPROVED EA-6B PROWLER COMBAT READINESS

Scott H. Swords-Lieutenant, United States Navy
B.S., Texas A&M University, 1990
Master of Science in Operations Research-March 1998
Advisor: John F. Raffensperger, National Research Council Post-Doctoral Associate
Second Reader: George W. Conner, Department of Operations Research

EA-6B Prowler crews conduct a variety of missions and are required to fly and train with sufficient regularity to maintain combat proficiency. These crews maintain this proficiency by completing regularly scheduled training qualifications. Squadrons determine their readiness level based on the percentage completion of these qualifications. Squadrons currently use an *ad hoc* method for scheduling training. This thesis develops a mixed integer program to plan monthly sorties, as a decision aid for squadron operations officers. The goal is to maximize squadron combat readiness by minimizing the number of aviators not fully combat-ready, subject to the number of flights available. The model is programmed in the GAMS language and uses a spreadsheet interface for both input and output. It is typically solved in 10 minutes on a Pentium 120 MHz PC with the OSL solver. The output is a matrix of pilots to flight assignments and aircrew to flight and seat assignments. This approach immediately yields a 10% improvement in average monthly readiness as compared to the *ad hoc* method and should be implemented as a methodology for scheduling monthly sorties.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel and Training

KEYWORDS: COMNAVAIRPACINST 3500.67C, EA-6B Prowler, Readiness, Scheduling, Training

OPTIMIZING UNITED STATES MARINE CORPS ENLISTED ASSIGNMENTS

Brian F. Tivnan-Captain, United States Marine Corps
B.S.M.E., University of Vermont, 1992
Master of Science in Operations Research-September 1998
Advisor: Robert F. Dell, Department of Operations Research
Second Reader: Hemant K. Bhargava, Information Systems Academic Group

The United States Marine Corps (USMC) has 156,000 active duty enlisted Marines and annually orders over 90,000 of them to permanently change station. The Commandant of the Marine Corps requires assignments of the "Right Marine, to the right place with the right skills and quality of life." USMC manpower planning uses staffing goals (billet requirements) to capture the Commandant's requirements, but, surprisingly, does not monitor how many Marines fill appropriate staffing goal billets. This thesis finds that although the staffing goals are completely achievable, only 45% of active duty Marines fill a staffing goal billet and 47% of staffing goal billets are under-staffed. The USMC has used the Enlisted Assignment Model (EAM) since the 1970s to help enlisted monitors determine assignments. EAM has several shortcomings. Among these, enlisted monitors reject most of EAM suggested assignments and EAM offers no measure of effectiveness to gauge the quality of its assignments. This thesis presents a network model, EAM-GLOBAL to optimize the by-name assignment of Marines to staffing goal billets. EAM-GLOBAL attempts to assign the "right Marines to the right places" while simultaneously balancing staffing shortages, allowing grade and military occupational specialty substitutions, and minimizing the costs of permanent change of station transfers within the continental United States.

AIR FORCE SPECIAL OPERATIONS FORCES LOGISTICS PLANNING AID

Brett S. Wagner-Lieutenant, United States Navy
B.A., Texas Tech University, 1991
Master of Science in Operations Research-September 1998
Advisor: LTC Charles H. Shaw III, Department of Operations Research
Second Reader: David A. Schrady, Department of Operations Research

This thesis compiles and creates logistics planning factors (usage/consumption rates) for the United States Special Operations Command (USSOCOM) and Air Force Special Operations Forces (AFSOF). The primary goal of this thesis is to provide logistics planning factors to AFSOF logistics planners to aid in the planning and execution process. Incorporating operations research methods to develop these planning factors, certain classes of supply were analyzed according to the specific type of mission, threat, duration, area of operations, number of personnel involved, and time. This thesis includes a graphical, PC-based AFSOF Logistics Planning Aid (AFSOFLOGPLN) using these planning factors. Since planners require a flexible, reliable, and user-friendly system, the logistics planning aid is developed in Microsoft's Excel with a graphical user interface. This planning aid lets the user input different platforms and mission scenarios and then it computes the logistics requirements to support the AFSOF platform or unit for that mission. Finally, this thesis makes recommendations to the Air Force Special Operations Command logistics planners and USSOCOM that would further improve logistics support for their forces in the future.

AN ANALYSIS OF AVIATION TEST SCORES TO CHARACTERIZE STUDENT NAVAL AVIATOR DISQUALIFICATION

Erich J. Wahl-Lieutenant, United States Navy
B.S., United States Naval Academy, 1988
Master of Science in Operations Research-March 1998
Advisor: Robert R. Read, Department of Operations Research
Second Reader: Samuel E. Buttrey, Department of Operations Research

The U.S. Navy uses the Aviation Selection Test Battery (ASTB) to identify those Student Naval Aviator (SNA) applicants most likely to succeed in flight training. Using classification and regression trees, this thesis concludes that individual answers to an ASTB subtest, the Biographical Inventory, are not good predictors of SNA primary flight grades. It also concludes that those SNA who score less than a six on the Pilot Biographical Inventory have a significantly higher disqualification rate in primary flight training than those SNA who score a six or higher. Those SNA who repeat the taking of the ASTB are more likely to disqualify from primary flight training than those SNA who pass it on the first attempt. Incidentally, significant differences exist in SNA performance and disqualification rates in Aviation Preflight Indoctrination among different racial groups. However, neither race nor gender is a significant factor in primary flight-training disqualification. Recommendations are provided to reduce the number of SNA entering the flight-training pipeline, if necessary, while significantly reducing the disqualification rate. Additionally, a method is given to identify those SNA most at risk of disqualifying from primary flight training.

OPTIMAL USE OF GERMAN ARMY MAINTENANCE RESOURCES

Joerg Wellbrink-Captain, German Army
M.S.(E.E.), University of Federal Armed Forces, Munich, 1987
Master of Science in Operations Research-March 1998
Advisor: Robert F. Dell, Department of Operations Research
Second Reader: Gordon H. Bradley, Department of Operations Research

The German Army's maintenance branch, having lost 25 percent of its soldiers since the end of the Cold War, has insufficient military personnel within maintenance units to maintain all combat units' equipment. The Army, therefore, purchases civilian man-hours (mhrs) to satisfy some required maintenance. This thesis develops a mixed integer linear program, named ADOPT (administrative order optimizer), to optimally assign combat units' equipment to maintenance units and to predispose a budget to purchase civilian mhrs. ADOPT also determines beneficial cross-training of soldiers from one maintenance type to another. Since it is not always possible to maintain all combat units' equipment, ADOPT minimizes the gap, prioritized by equipment types, between needed maintenance mhrs and available military and civilian maintenance mhrs. ADOPT provides a tool to determine and evaluate options and principles that impact the readiness of a German Army Division's materiel. ADOPT validates its effectiveness with data of Military District VIII/ 14th Mechanized Infantry Division. Results indicate a potential budget saving of one-third when cross training of maintenance soldiers from one maintenance type to another is allowed. ADOPT also shows that the regional principle (assigning common combat units' equipment to the nearest maintenance units) is inefficient.

AN EXPLORATORY ANALYSIS OF CORRECTIVE MAINTENANCE DURING EXTENDED SURFACE SHIP DEPLOYMENTS

G. Karl Werenskjold-Lieutenant, United States Navy
B.S., University of Colorado, 1990
Master of Science in Operations Research-September 1998
Advisor: Donald P. Gaver, Department of Operations Research
Second Reader: David A. Schrady, Department of Operations Research

The Chief of Naval Operations (CNO) Strategic Studies Group (SSG) XVI study of 1997 proposes to deploy ships for three year periods and rotate crews. This concept is called *Horizon*. An object-oriented, discrete-event simulation is written in Java to stimulate this extended deployment model and evaluate the corrective maintenance requirements for a single-ship deployment. The simulation estimates the mean on- and off-station times of the ship, the mean time between shore-based repair, and the mean operational availability of the ship. The simulation allows the user to perform sensitivity analysis on the input values to determine the significance of the results based upon the measures of the model. The results of this thesis show that the number of shore-base maintenance requirements is affected by inputs of the mean time-to-failure, logistics delay time, and percent of organic repair of the ship.

DEMONSTRATING THE REQUIREMENT FOR AMPHIBIOUS READY GROUP (ARG) REPLENISHMENT IN SEA-BASED LOGISTICS OPERATIONS

Max A. Willey-Lieutenant, United States Navy
B.S., Old Dominion University, 1989
Master of Science in Operations Research-December 1997
Advisor: David Schrady, Department of Operations Research
Second Reader: Arnold Buss, Department of Operations Research

Operational Maneuver From the Sea (OMFTS) is a new concept under development by the Marine Corps. OMFTS is a warfighting concept that revises the way combat power is projected in littoral regions in that it uses the sea as a maneuver space and safe haven for logistics, while further adopting *ship to objective* operations. Sea-Based Logistics (SBL) uses the Amphibious Ready Group (ARG) ships to provide a sea-base from which combat forces ashore are directly sustained. To function in this new capacity, the ARG units need replenishment to maintain high stockage levels of fuel, ammunition, and stores. This thesis develops a computer simulation for modeling the logistical support needed for ARG units functioning in a sea-base role for supporting combat forces ashore.

KEYWORD: Underway Replenishment (UNREP), Sea-Based (SBL), OMFTS, Amphibious Ready Group

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

ANALYSIS OF AMPHIBIOUS SHIP LIFT CAPABILITY

Eric D. Williams–Lieutenant, United States Navy
B.A., University of Illinois, 1992
Master of Science in Operations Research-September 1998
Advisor: Samuel E. Buttrey, Department of Operations Research
Second Reader: Ronald L. Brown, Department of Operations Research

Amphibious ship lift is crucial in supporting operations of Marine Air Ground Task Forces (MAGTF) for a wide range of conflicts. This thesis examines three different aspects of amphibious ship lift capability. First, gross lift capabilities of all amphibious ships in the Navy today are determined. Since some storage space on board a ship is required for access, tie-downs, and other considerations, the second step of this thesis is to use historical load-out data from six-month deployments to derive expected net lift capability from gross lift capability. A three-ship Amphibious Ready Group (ARG) is traditionally required to support a six-month MAGTF deployment. The final part of this thesis utilizes a linear program to determine specific ship combinations that optimize ARG lift capability for both the Pacific and Atlantic Fleets.

DoD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles-Ships and Watercraft

KEYWORDS: Amphibious Ship, Broken Stowage Factor, Amphibious Ready Group (ARG)

SOLUTION OF LARGE-SCALE ALLOCATION PROBLEMS WITH PARTIALLY OBSERVABLE OUTCOMES

Kirk A. Yost-Lieutenant Colonel, United States Air Force
B.S., United States Air Force Academy, 1980
M.S., Rensselaer Polytechnic Institute, 1986
Doctor of Philosophy in Operations Research-September 1998
Advisor: Alan R. Washburn, Department of Operations Research
Committee: Gerald G. Brown, Department of Operations Research
Robert F. Dell, Department of Operations Research
Guillermo Owen, Department of Mathematics
Craig M. Rasmussen, Department of Mathematics

Methods were developed for optimally solving problems that require allocating scarce resources among activities that either gather information on a set of objects or take actions to change their status. Also, the information gathered on the outcomes of the actions taken may be erroneous. The latter situation is called *partial observability*, and methodology available prior to this dissertation is combinatorially intractable for problems with more than one object. Two previously-uncombined methods were used–linear programming (LP) and partially observable Markov decision processes (POMDPs) – to construct a decomposition procedure to solve the resulting large-scale allocation problem with partially observable outcomes. Theoretically it was shown that this procedure is both optimal and finite; in addition, improvements were developed to the procedure that reduce runtimes on test problems by 95%. It was demonstrated that the procedure on a small targeting problem with a known analytical solution, as well as a large-scale military example concerned with allocating aircraft sorties, weapons, and bomb-damage assessment sensors to targets. Finally, analytical bounds were developed on the expected objective function values of a related allocation problem with more stringent resource constraints, and present a simulation-based approach to estimate the distributions of the outcomes for that model.

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center   2
    8725 John J. Kingman Rd., STE 0944
    Ft. Belvoir, VA 22060-6218

2. Dudley Knox Library, Code 013   2
    Naval Postgraduate School
    411 Dyer Rd.
    Monterey, CA 93943-5101

3. Associate Provost and Dean of Research   2
    Code 09
    Naval Postgraduate School
    Monterey, CA 93943-5138

4. Chair   5
    Department of Operations Research
    Naval Postgraduate School
    Monterey, CA 93943-5000

5. Associate Chair for Research   5
    Department of Operations Research
    Naval Postgraduate School
    Monterey, CA 93943-5000

6. Dean, Division of Operational and Policy Sciences   1
    Code 08
    Naval Postgraduate School
    Monterey, CA 93943-5000

7. Provost and Academic Dean   1
    Code 01
    Naval Postgraduate School
    Monterey, CA 93943-5000